Massachusetts

Erosion and Sediment Control Guidelines for Urban and Suburban Areas

A Guide for Planners, Designers, and Municipal Officials

Department of Environmental Protection, Bureau of Resource Protection, One Winter Street 5th Floor, Boston, MA 02108

MASSACHUSETTS EROSION AND SEDIMENT CONTROL GUIDELINES FOR URBAN AND SUBURBAN AREAS

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Preface

In 1975, the Soil Conservation Service, USDA, in Massachusetts published the first edition of the ***Guidelines for Soil and Water Conservation in Urbanizing Areas of Massachusetts***. This was a 300+ page book dealing with a wide variety of conservation-related urban problems and situations encountered throughout the state of Massachusetts.

After the third printing and in 1982, the Soil Conservation Service began an update and revision to bring this volume up to date. At the same time, the format was changed from a single volume to a series of ***"Massachusetts Conservation Guides"*** - each keyed to a specific subject area. Only the first two of the proposed five guides were published: ***Volume I - Erosion & Sediment Control in Site Development and Volume II - Vegetative Practices in Site Development.***

In late 1993, realizing the need for a complete, up-to-date volume for persons undertaking to plan, install or review urban developments in the state, the State Commission for Conservation of Soil, Water and Related Resources took the lead to prepare a complete and comprehensive revision of this handbook. The Commission enlisted the aid of the Executive Office of Environmental Affairs, the Massachusetts Department of Environmental Protection, and the Natural Resources Conservation Services (formerly the Soil Conservation Service) of the U. S. Department of Agriculture. This group, working through the Franklin, Hampden, Hampshire Conservation Districts-Division V, undertook to update the original document and this volume is the culmination of their efforts.

There are numerous excellent references available to the general public covering the fields of erosion and sediment control, pollution control, and stormwater management. This guide draws upon many of those documents. It is meant to provide the lay person who is involved in projects which affect the land and water resources in Massachusetts with background information. Further details may be found in other documents, which are referenced as sources of information.

This guide deals primarily with conservation measures and conservation practices. These practices are generally referred to as ***"Best Management Practices"*** or ***"BMPs"*** and is intended to be a companion handbook with the recently prepared ***"Mega-Manual"*** prepared by the Massachusetts Department of Environmental Protection.

Only limited detail is included about the soils, engineering, hydrology, plant materials and other knowledge that is needed to plan and design a potential project. It is intended only as a guide and should be used as such. A professional planner should be engaged to prepare the proposal and a professional engineer for the detailed erosion and sediment control plan and designs, drawings, and specifications.

The contents of this guide is based on material almost entirely in the public domain, published by federal or state agencies or public educational institutions. It should not be interpreted as necessarily representing the policies or recommendations of other referenced agencies or organizations nor of the agencies who sponsored this revision. The mention of trade names, products, companies or publications does not constitute an endorsement, but are used for clarification.

In the fall of 1994, the USDA Soil Conservation Service was renamed the Natural Resources Conservation Service. Numerous references used herein were published as Soil Conservation Service documents and have not been renamed or revised at this date.

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Erosion and Sedimentation

As undeveloped areas are converted to urban uses, the natural vegetation is removed, land slopes may be excavated or filled, ground surfaces are paved over, and stream channels are modified. The result is an increase in runoff and a reduction in the ability of the land to provide natural treatment to the runoff.

Land is disturbed and exposed to erosion by wind and water during this period of conversion. Soil displaced by erosion contributes to both onsite and offsite damages. A portion of the soil reaches the state's streams, lakes, and coastal waters as sediment.

Erosion

Erosion is the wearing away of the land surface by running water, wind, ice, or other causes. Soil erosion is usually caused by the force of water falling as raindrops and by the force of water flowing in rills and streams. Raindrops falling on bare or sparsely vegetated soil detach soil particles. Water running along the surface of the ground picks up these particles and carries them along as it flows downhill towards a stream system.

As the runoff gains in velocity and concentration, it detaches more soil particles, cuts rills and gullies into the surface of the soil and adds to its sediment load. The merging rivulets produce larger channels which have a larger volume and usually higher velocity, and a greater capacity to remove sediment and transport it downstream.

The greater the distance the water runs uncontrolled, the greater its erosive force and the greater the resultant damage. Moreover, control becomes more difficult as the distance and volume increases.

Soil erosion is also caused by the force of wind blowing across unprotected ground. Open gravel pits and construction sites that have been stripped of vegetation are especially vulnerable to wind erosion. The wind-borne sediments land in streams, roads, and neighboring lots. Blowing dust is a nuisance, and can be a hazard on especially windy days. Wind erosion in areas undergoing development can be controlled best by keeping disturbed areas small and by stabilizing and protecting them as soon as possible.

Sedimentation

Sedimentation is the deposition of soil particles that have been transported by water and wind. The quantity and size of the material transported increases with the velocity. Sedimentation occurs when the medium, air or water, in which the soil particles are carried is sufficiently slowed long enough to allow particles to settle out. Heavier particles, such as gravel and sand, settle out sooner than do finer particles, such as clay.

The length of time a particle stays in suspension increases as the particle size decreases. The coarsest, heaviest particles (gravel) are transported only a short distance, while water flow is at its maximum. Smaller, lighter particles (sand) move by rolling or bouncing along the surface, or stay in suspension over short distances while the water velocity is fairly high. Because of their slow settling rate, fine silt particles generally remain for several hours in suspension in the storm runoff that originally moved them. The still finer colloidal clays stay in suspension for very long periods and contribute significantly to water turbidity.

Factors that Influence Erosion

There are four principal factors that influence the potential for erosion: soils, surface cover, topography, and climate. These factors are interrelated in their effect on erosion potential.

Variability in terrain, soils, and vegetation makes erosion control unique to each development. Erosion and resulting sedimentation generally occur in Massachusetts only when the soil is disturbed. The seriousness of the problem is a function of the topography and size of the area disturbed, the characteristics of the soils, the climate, and the vegetative cover.

As a rule of thumb:

- The more fine-grained material there is in a soil, the greater the amount of material that will be picked up by water flowing across its surface;
- The steeper the slope, the faster the water will move, thus being able to carry more soil; and,
- The larger the unprotected surface, the larger the potential for problems.

Soils

The vulnerability of a soil to erosion is known as its erodibility. Key factors that influence erodibility are:

- Soil texture (proportions of sand, silt, and clay)
- Organic matter content
- Soil structure (arrangement of soil particles)
- Soil permeability (the ease by which water passes through the soil)

Soil texture is described by the proportions of sand, silt, and clay in the soil. High sand content gives a coarse texture, which allows water to infiltrate readily, reducing runoff. A relatively high infiltration rate coupled with resistance to transport by runoff results in a low erosion potential. Soils containing high proportions of silt and very fine sand are most erodible. Clay particles and organic matter in the soil tend to bind it together into aggregates, thereby reducing erodibility. When clay erodes, however, the particles settle out very slowly.

Organic matter, such as plant material, humus, or manure, improves soil structure, increases water-holding capacity, and may increase the infiltration rate. It reduces erodibility and the amount of runoff.

Soil structure is determined by the shape and arrangement of soil particle. A stable, sharp, granular structure absorbs water, readily, resists erosion by surface flow, and promotes plant growth. Clay soils or compacted soils have slow infiltration capacities that increase runoff rate and create severe erosion problems.

Soil permeability refers to a soil's ability to transmit air and water. Soils that are least subject to erosion from rainfall and shallow surface runoff are those with high permeability rates, such as well-graded gravels and gravel-sand mixtures. Loose, granular soils reduce runoff by absorbing water and by providing a favorable environment for plant growth. "Well-graded" soils are those which contain a wide range of particle sizes. Well-drained and well-graded gravels and gravels and mixtures with little or no silt have low erodibility to sheet flow, but wash easily under concentrated flow. Coarse, granular soils also have high permeabilities and a sufficiently good infiltration capacity to prevent or delay runoff.

Surface Cover

Vegetative cover is extremely important in controlling erosion. It performs these functions:

- Shields the soil surface from the impact of falling rain,
- Holds soil particles in place,
- Helps to maintain the soil's capacity to absorb water,
- Slows the velocity of runoff.

Soil erosion and sedimentation can be significantly reduced by scheduling construction activities to minimize the area of exposed soil and the time of exposure. Special consideration should be given to the maintenance of existing vegetative cover on areas of high erosion potential such as erodible soils, steep slopes, drainageways, and banks of streams.

Vegetation slows runoff velocity, disperses flow, and promotes infiltration and deposition of sediment. Plants remove water from the soil, increasing the capacity to absorb water. Plant roots help maintain soil structure.

The type and condition of ground cover influence the rate and volume of runoff. Impervious surfaces protect the area covered, but prevent infiltration and decrease the "time of concentration" for runoff, thereby increasing high peak flow and potential for stream and channel erosion. Covers such as mulches, paving, and stone aggregates also protect soils from erosion.

Topography

Topographic features distinctly influence erosion potential. Watershed size and shape, for example, affect runoff rates and volumes. Slope length and steepness are key elements in determining the volume and velocity of runoff and erosion risks. As both slope length and gradient increase, the rate of runoff increases and the potential for erosion is magnified. Swales and channels concentrate surface flow, which results in higher velocities. Exposed south-facing soils are hotter and drier, which makes vegetation more difficult to establish.

Climate

Where storms are frequent, intense, or of long duration, erosion risks increase. The high erosion risk period of the year results from seasonal changes in temperature, as well as variations in rainfall. When precipitation falls as snow, no erosion will take place immediately. In the spring, however, the hazards will be high. Most plants are still dormant. The existing vegetative cover is less able to buffer the raindrops. The ground is still partially frozen, or else saturated from melting snow, and its absorptive capacity is reduced.

Exposed areas should be well stabilized in the Fall, before the period of high erosion risk in the Spring.

The frequency, intensity, timing, and duration of rainfall are fundamental factors in determining the amounts of runoff produced. The ability of runoff to detach and transport soil particles also increases as both the volume and the velocity of runoff increase. Development should be scheduled to take place during the periods of low precipitation and low runoff.

In Massachusetts, soil erosion is caused primarily by runoff water from rainfall and snowmelt. Wind erosion is a problem for farmers on the broad plains adjoining the Connecticut River, and can be a problem for exposed soils at construction sites also.

Areas where the soil has been disturbed and left bare by construction activities should be revegetated early enough in the Fall so that a good cover is established before cold weather comes and growth stops until the spring. A good cover is defined as vegetation covering 75 percent or more of the ground surface. October is too late to seed and obtain a good cover for the winter. Where good cover has not been established, structural stabilization methods, such as hay bales, silt fences or anchored mulch, must be used.

Effects of Urbanization

Before colonial times, most of Massachusetts was forested. The forest system provided protection by intercepting rainfall in the tree canopy, reducing the possibility of erosion and the deposition of sediment in waterways. The trees and the forest duff layer absorbed large amounts of runoff, releasing it slowly to the streams by percolation through the soil.

As settlement occurred and the population grew, land was cleared for buildings, fields, pastures and roads. Low spots, often wetlands, were filled. Today, as areas are converted to urban uses, the natural vegetation is removed, land slopes are modified, areas are paved over.

After vegetated terrain is cleared, the additional area of compacted and impervious surfaces changes the hydrologic characteristics. Volume of surface runoff and the rate of flow increases. Ground water recharge decreases. Runoff that was previously slowly released to streams by filtering through the soil now runs quickly off the surface directly into the streams. This increases velocity and quantity of flow causing streambank erosion and general habitat destruction. Sediment from eroded and unstable streambanks and cleared areas is deposited downstream; filling ponds, streambeds and stormwater facilities. Summer base flows are reduced.

In addition to the increase in impervious surfaces, urbanization creates a significant amount of ground surface modification. Natural drainage patterns are modified and runoff is transported via road ditches, storm sewers, drainage swales, and constructed channels. These modifications increase the velocity of the runoff which in effect decreases the time that it takes for runoff to travel through the watershed. This decreased time creates higher peak discharges.

Vegetative cover on an undisturbed site protects the ground surface. Removal of that cover increases the site's susceptibility to erosion. Disturbed land may have an erosion rate 1,000 times greater than the pre-construction rate. Proper planning and use of control measures can reduce the impact of man-induced accelerated erosion.

The major problem associated with erosion on a construction site is the movement of soil off the site and its impact on water quality. Millions of tons of sediment are generated annually by construction activities in the United States. The rate of erosion on a construction site varies with site conditions and soil types but is typically 100 to 200 tons per acre and may be as high as 500 tons per acre.

Under natural conditions, stream channels will normally handle, at bankfull, capacity the peak discharge from a storm that could be expected once every two years. The increased discharge caused by urbanization will cause out-of-bank flooding more frequently. The stream channel begins to widen and deepen to accommodate the increased flow and to change grade to handle the increased velocity. Eventually the increased sediment transport can lead to problems downstream.

Urbanization can be a significant cause of pollution problems due to sediment loads, with both short-term and long-term impacts. Short-term changes in water quality can restrict recreational activities, stress aquatic organisms, and damage shellfish beds. Long-term accumulation of pollutants into receiving waters can create particularly difficult to correct problems such as eutrophication, polluted groundwater, and contaminated sediments.

Erosion and Sediment Hazards Associated with Site Development

Hazards associated with site development include increased water runoff, soil movement, sediment accumulation, and higher peak flows caused by:

- Removal of plant cover and a large increase of soil exposed to erosion by wind and water.
- Changes in drainage areas caused by regrading the terrain, diversions, or road construction.
- A decrease in the area of soil which can absorb water because of construction of streets, buildings, sidewalks, or parking lots.
- Changes in volume and duration of water concentrations caused by altering steepness, distance, and surface roughness.
- Soil compaction by heavy equipment, which can reduce water intake of soils to 1/20 or less of the original rate.
- Prolonged exposure of unprotected sites and service areas to poor weather conditions.
- Altering the groundwater regime may adversely affect drainage systems, slope stability, survival of existing vegetation, and establishment of new plants.
- Exposing subsurface materials that are too rocky, too acid, or otherwise unfavorable for establishing plants.
- Obstructing streamflow by new buildings, dikes, and landfills.
- Inappropriate timimng and sequaence of construction and development activites.
- Abandonment of sites before construction is completed.

Analyzing the Project Site

Most soil and water management problems encountered during land use change are caused by one or more of the following:

- Soil Limitations,
- Sloping Land,
- Drainage Problems
- Exposed Soil.

Soil Characteristics and Limitations

Soil characteristics have a major influence on how a proposed development site can best be utilized. Characteristics such as texture, permeability, and structure affect a soil's erodibility. Other characteristics that affect the potential, and the limitations, of a site include natural drainage, depth to seasonal water table, depth to bedrock, flood hazard potential, natural fertility, and engineering, physical, and chemical properties.

Significant differences in soil properties can occur within short distances. Some soils are seasonally wet or subject to flooding. Some are shallow to bedrock. Some are too unstable to be used as a foundation for buildings or roads. Finer-textured or wet soils have severe limitations for use as septic tank absorption fields. A site with a high water table is poorly suited to basements or underground installations. Depth to bedrock or to a cemented pan (cemented or hardened subsurface layers), large stones, slope, and the hazard of cutbanks caving affect the stability of ditch banks and the ability of construction equipment to perform excavation or grading work. Knowledge of the soil properties is of great value in deciding how to utilize the project site.

Drainage

Drainage is the removal of excess surface and subsurface water from the soil. How easily and effectively the soil is drained depends on the depth to bedrock, to a cemented pan, or to other layers that affect the rate of water movement; permeability; depth to water table (depth to standing water if the soil is subject to ponding): slope; susceptibility to flooding; subsidence of organic layers; and potential frost action.

Some soils are so wet that it would be difficult to use them for development. Two examples are the Scarboro soil series ("mucky fine sandy loam"), found on outwash plains and terraces; and the Whitman soil series (fine sandy loam) found in some upland areas. Poorly-drained soils such as Ridgebury and Walpole have severe limitations for houses, small commercial buildings, or lawns. Even moderately-well-drained soils such as the Woodbridge, Sudbury, or Deerfield series would present moderate to severe limitations for some development purposes.

Depth to seasonal high water table

Areas with a high water table should either be avoided or steps taken to control the condition. A high water table can cause malfunctioning septic systems, damp basements, and uneven foundation settlement.

Depth to bedrock

If the rock is soft or fractured, excavations can be made with trenching machines, backhoes, or small rippers. If the rock is hard or massive, blasting or special equipment generally is needed for excavation.

Flood hazard potential

Flooding, the temporary covering of the soil surface by flowing water, is caused by overflowing streams, by runoff from adjacent slopes, or by inflow from high tides.

Ability to support vegetation

"Tilth" (physical condition of the soil related to ease of tillage, fitness as a seedbed, and impedance to seedling emergence and root penetration) is important to the germination of seeds and the infiltration of water into the soil. Soils that have good tilth are generally granular and porous.

Fertility tends to be low for soils in their natural state. Most soils in the Northeast are acid. They require applications of lime to lower acidity sufficiently for lawns and other vegetation to do well. There are some exceptions; for example some shrubs prefer acid soils.

Soil Survey Reports

Soil survey reports offer detailed information on the soil characteristics. These reports contain soil maps, soil descriptions, and soil interpretation tables. They have been published for most areas of Massachusetts. Copies are available for review at the local Conservation District office.

Soil surveys maps are aerial photographs on which soil scientists have drawn boundaries of natural soil bodies, identifying each as a specific map unit. A map unit delineation on a soil map represents an area dominated by one major kind of soil or an area dominated by several kinds of soil, on the basis of soil series and soil phase. Map unit descriptions and accompanying tables provide detailed information on each, as well as interpretations on their use for numerous purposes.

Examples of two tables are shown in the accompanying figures.

A soil series is made up of soils that have horizons (soil layers) similar in arrangement and characteristics. Soils of one series can differ in texture, underlying material, slope, stoniness, wetness, etc. On the basis of such differences, a soil series is divided into soil phases. The smallest map unit that is practical to identify is three to five acres.

Every map unit generally has some soils that belong to other taxonomic classes. These soils are known as inclusions. The inclusion may be similar to the dominant soil and therefore may not affect the use or management of the soil. On the other hand, the inclusion may be contrasting and therefore require different management and may affect the potential use of the soil mapping unit. Inclusions could affect the site specific use of an area but may have little or no effect on broader land use determinations.

Soil survey reports are very useful to planners, contractors, engineers, and local officials. Planners can evaluate the effects of specific land uses in an area. Contractors can identify potential sources of sand and gravel, topsoil, and roadfill. They can use the survey to determine the areas where high water table, restrictive layers or bedrock may hinder excavation. Engineers and local officials may also use the survey to plan for waste disposal and site development.

The reports contain descriptions for each soil series, with information on the composition of each layer of the soil profile; to a depth of at least 60 inches. There are tables evaluating the limitations for use of each soil series. Other tables contain engineering, physical, and chemical properties.

Soil survey reports should be supplemented with onsite soil investigation for a specific land use.

Slopes

Runoff velocity increases as slope length and gradient increase. As the velocity increases, so does its capacity to detach and transport soil particles. In general, the flatter and shorter a slope, the slower the runoff velocity and the greater the infiltration rate on that slope.

Excerpts from tables in typical Soil Survey report

Table 11: Building Site Development

Some terms that describe restrictive soil features are defined in the glossary. See text for definitions of “slight,” “moderate,” and “severe.” Absence of and entry indicates that the soil was not rated. The information on this table indicates the dominant soil condition but does not eliminate the need for onsite investigation.

Soil name and map symbol	Shallow Excavations	Dwellings without basements	Dwellings with basements	Small Commercial Buildings	Local roads and streets	Lawns and landscaping
BoM------ Brookfield	Slight----------	Slight-------	Slight-------	Slight-------	Moderate: Frost Action	Moderate: Large stones
BoC------ Brookfield	Moderate: Slope	Moderate: Slope	Moderate: Slope	Severe: Slope	Moderate: Slope, Frost action	Moderate: Large stones, slope
Bod------ Brookfield	Severe: Slope	Severe: Slope	Severe: Slope	Severe: Slope	Severe: Slope	Severe: Slope
BrC*------ Brookfield	Moderate: Slope	Moderate: Slope	Moderate: Slope	Severe: Slope	Moderate: Slope, Frost action	Moderate: Large stone, slope
Brimfield	Severe: Depth to rock	Severe: Depth to rock	Severe: Depth to rock	Severe: Slope, Depth to rock	Severe: Depth to rock	Severe: Thin Layer

Table 15: Engineering Index Properties

The symbol< means less than; > means more than. Absence of an entry indicates that data were not estimated.

Soil name and map symbol	Depth	USDA texture	Classification		Fragments >3 inches	% passing sieve number				Liquid Limit	Plasticity Index
			unified	AASNTO		4	10	40	200		
BoM,BoC, BoD---- Brookfield	Inches 0-2 2-65	Fine sandy loam, Gravelly sandy loam, gravelly fine sandy loam	SM, ML, GM SM,GN	A-2, A-4, A-2, A-4	% 15-30 0-15	65-100 65-100	60-95 60-95	40-80 40-70	25-65 25-65	% <25 ----	NP-5 NP
BrC*, BrE* Brookfield-----	0-2 2-65	Fine sandy loam, Gravelly sandy loam, gravelly fine sandy loam, fine sandy loam	SM, ML, GM SM, GN	A-2, A-4 A-2, A-4	15-30 0-15	65-100 65-100	60-95 60-95	40-80 40-70	25-65 25-45	<25 ----	NP-5 NP
Brimfield	0-2 2-15 15	Fine sandy loam Gravelly fine sandy loam, Sandy loam, Loam Unweathered bedrock	SM, ML, GM SM, ML, GM -----	A-2, A-4 A-2, A-4 ____	15-30 0-15 -------	65-100 65-100 ------	60-95 60-95 -------	40-85 40-80 ------	20-65 20-65 ------	<25 <25 -------	NP-5 NP-5 -------

Status of Soil Survey Reports in Massachusetts, as of January 1996.

Berkshire County	Published
Franklin County	Report being updated
Hampden and Hampshire Counties, Western	Published
Hampshire County, Central	Published
Hampden County, Central	Published
Hampden and Hampshire Counties, Eastern	Published
Worcester County, Northwestern	Awaiting publication
Worcester County, Northeastern	Published
Worcester County, Southern	Awaiting publication
Middlesex County	Awaiting publication
Essex County, Northern	Published
Essex County, Southern	Published
Norfolk and Suffolk Counties	Published
Plymouth County	Report being updated
Bristol County, Northern	Published
Bristol County, Southern	Published
Barnstable County	Published
Dukes County	Published
Nantucket County	Published

Removal of existing vegetative cover from slopes increases the vulnerability of the slopes to erosion. Vegetation retards runoff velocity and root systems hold soil particles in place. Vegetation maintains the soils' capacity to absorb precipitation.

Soils are most vulnerable to erosion where highly erodible soils and steep or long slopes appear in combination, and where surface soils are low in fertility and ability to support vegetation.

Practices to Divert Runoff

Runoff can be diverted from slopes that are exposed during development by using diversions to intercept runoff and keep it away from the slope face. A diversion extends across a slope, usually a combination of dike and ditch. Diversions can be used at intervals across the slope face to reduce slope length. Diversions are also used to collect runoff from a construction site and divert it to a sediment retention trap or pond.

Diversions can be bare channels, vegetatively stabilized channels, or lined channels (paving, erosion control fabric, etc.). Temporary diversions must remain in place until slopes have been permanently restabilized.

Diversions concentrate the volume of surface runoff. As a result, they also increase its erosive force. It is important to plan in advance for the disposal of runoff collected by diversions. Runoff must be released onto a stabilized area to reduce its erosion potential. In some cases this can be simply achieved by gradually reducing the gradient of the diversion channel.

Slope Drains

If runoff cannot be satisfactorily disposed of by conveying across a slope, it can be drained over the face of the slope itself. Slope drains can run down the surface of the slope as a sectional downdrain, paved chute, or a pipe placed beneath the surface of the slope.

On-surface sectional downdrains are usually corrugated metal, or plastic pipe. These slope drains are temporary. For permanent installations; paved chutes with a surface of concrete or bituminous material, or subsurface pipes are used.

Compact the soil carefully at the mouth of the slope drain and anchor it adequately. Otherwise, undercutting can occur at the lip of the slope drain and under the drain.

At the slope drain outlet, energy dissipators are frequently necessary. Failure to utilize an “energy dissipater,” such as rock riprap, can result in serious erosion problems at the outflow end of the slope drain. An energy dissipater breaks up the flow of water and reduces velocity to a non-erosive level.

Retaining Walls, Slope Protection

Retaining walls may be used to reduce extreme slope gradients, dividing a slope into a series of shorter, flatter segments and structural vertical walls. Retaining walls can be used in a situation where the builder is trying to keep existing mature vegetation. The cost of building retaining walls is often justified because of the maintenance costs that are saved on areas that would be difficult or impossible to stabilize otherwise.

Slope paving (e.g. asphalt or concrete paving, rock lining) may also be used to protect steep slopes that cannot be vegetated. If possible, use permeable materials.

Slope Stabilization Measures

Another way to stabilize slopes is to reduce their steepness. The selection of the appropriate grade for cut and fill slopes should be based on several considerations. The stability of the soil, its drainage characteristics, and its erodibility should be considered first.

If the slope gradient is flattened, the overall length of the slope increases, and this increases the amount of surface area subject to erosion. It is easier, however, to establish vegetation on a flatter slope.

Slope surfaces can be roughened by running wheeled construction equipment across the slopes, or tracked equipment up and down the slope face. This reduces the velocity of water flowing down the slope and increase infiltration rates. The rough surface holds water, seed, and mulch better than a smooth slope. The grooves created by the construction equipment should run across the slope horizontally, and not up and down the slope. Slopes can also be scarified (loosened with a harrow) to produce desired surface roughness.

Drainage

Protecting streams and waterways on or near sites undergoing development and protecting areas downstream from development involves three goals:

- The increased sediment loads carried by surface runoff from areas under construction must not be allowed to enter streams.
- Streambanks must be protected from erosion hazards caused by increases in runoff volume and velocity.
- The rates of release of increased volumes of runoff into streams and waterways and the velocity of flow in stream channels must be controlled.

Contact the local Conservation Commission regarding any stream crossing or other work conducted in a wetland resource area. The Massachusetts Wetland Protection Act requires that the proponent file a “Request for Determination of Applicability” or “Notice of Intent.”

There are several identifying characteristics for streams that are particularly vulnerable to erosion. Streams which have a small channel capacity and steep banks are very susceptible to erosion. Streams which flow through areas of erodible soil, and streams with sharp meanders or bends in the channel alignment are also prone to erosion.

Streambank Stabilization Measures

Maintain existing vegetation on streambanks. Streambank vegetation helps stabilize the soil, slows runoff and dissipates its erosive energy, and filters sediment from runoff.

To prevent the destruction of streambank vegetation, stream crossing and construction traffic along the banks must be controlled. Culverts and temporary bridges should be constructed only as a last alternative.

Vegetative Measures

When streambanks must be disturbed, or where existing vegetative cover is inadequate, grass or grass-legume mixtures may be established. Vegetative restabilization should be done immediately after streambank grading has been completed. Grass and legume vegetation is recommended for the protection of streambanks. Woody vegetation (shrubs) may be used if ice damage is a potential problem.

As soon as planting or seeding has been completed, banks should be mulched and the mulch securely anchored. Straw with a plastic-emulsion tacking agent, excelsior blanket, a netting over straw, or similar materials may be used. In recent years manufacturers have developed many new products for soil stabilization.

It is important to check periodically and repair areas where vegetation has failed.

Structural Measures

Streambanks can be protected from erosion by structural as well as vegetative measures. If vegetation will not provide sufficient protection, banks can be protected with revetments and deflectors.

Where sharp bends occur or where there are constrictions in the stream channel (such as culverts, bridges, or grade control structures), structural treatment may be necessary. Riprap, gabions, and concrete paving are often used to protect and reinforce a stream bank. Deflectors, consisting of jetties or pilings that angle outward from the bank in a downstream direction, may also be used to keep erosive currents away from vulnerable bank areas.

Grade Control Structures

Grade control structures can be used to reduce the channel gradient, thereby reducing the velocity of flow in a channel. Check dams, weirs, and drop spillways, made of a variety of materials, both temporary and permanent, reduce channel grade and dissipate the energy of flowing water. These structures concentrate the volume of water and increase velocity of flow, therefore, special care must be taken to prevent undercutting at the toe of the structure and erosion of the banks.

Sediment Traps or Basins

The first step in preventing sediment from entering streams and waterways is to control erosion on construction sites. The second is to trap sediment transported by runoff before it reaches streams and waterways or leaves the construction site. Runoff must be detained for a sufficient period of time to allow the suspended soil particles to settle.

Vegetative filter strips between streams and development areas can slow runoff and filter out sediment.

Sediment traps can be constructed in drainageways. Sandbags, straw bale barriers, and excavated sediment traps, placed at regular intervals within a drainage channel, are easy and economical to construct. Sandbag barrier sediment traps are constructed of bags filled with sand or crushed rock and stacked in an interlocking manner designed to trap sediment and reduce velocity of flow.

Straw bale barrier sediment traps are constructed of bales of hay or straw stacked and staked in place. Tying the bales to stakes with wire provides additional stability. Soil excavated from the drainage channel should be compacted along the upstream face of the barrier. Piping, or undercutting, can be reduced by setting the bales at least six inches into the bottom of the drainway and compacting excavated soil along the upstream side. Sediment traps require cleaning out periodically; and they should be checked after heavy rains to repair any damage and remove accumulated sediment.

Streams may also be protected from increased sediment loads by trapping runoff in sediment basins before it is released into stream channels. In addition to trapping sediment, these basins are designed to release runoff at nonerosive rates. Sediment basins usually consist of an earthen dam, a spillway to carry normal water flow, and an emergency spillway for storm flows. Construct sediment basins before clearing and grading of the main site begins. They are generally located at or near the low point of the site. Sediment basin outlets must be stabilized.

Surface runoff, and runoff intercepted by erosion control measures such as diversions, should be conveyed in erosion-resistant drainageways and released to stabilized areas, storm sewers, or sediment basins. The drainageways should be designed to insure that runoff is transported without risk of erosion or flooding.

The development should be planned to maintain and utilize the existing drainageways. Increases in runoff volume and velocity because of changes in soil and surface conditions during and after construction must be anticipated. Where the capacity of the natural site drainage channels is exceeded, additional capacity, stabilizing vegetation, or structural measures will be needed.

Bare Channels

Bare channels should be used with caution, and only in areas where the channel slope is quite flat. In areas where the soils have moderate to high erosion potential, stabilization techniques will need to be a part of the design.

Grassed Waterways

Waterways are designed to transport excess surface water from diversions or natural concentrations of flow in a stable channel. Grassed waterways are vegetatively stabilized channels. Jute netting, paper twine fabric, excelsior blankets, and various other mulching techniques are frequently used to protect channels until vegetation becomes well established. In some vegetatively lined channels, bank protection may also be necessary. Riprap is a commonly used material.

Lined Channels

Linings are necessary in drainageways where: vegetation cannot be established because flow is of long duration in the channel, runoff velocities or concentrations are high, erodible soils exist or slopes are very steep. Concrete paving and riprap are commonly used channel linings. In general, vegetative stabilization and the use of permeable channel linings, such as riprap, are preferred to the use of impermeable linings, such as concrete or grouted riprap.

Inlet Protection

The capacity of the storm sewer system can be severely impaired by sediment deposits. Sediment should be prevented from entering an enclosed storm sewer by temporary sediment traps and filters at system inlets. Filters made of crushed rock, sod, or straw bales can be placed at inlets where sediment traps cannot be constructed. It is essential to check traps and filters regularly and remove accumulated sediment.

Enclosed Drainage

The capacity of vegetated drainage channels may be exceeded by the increases in runoff caused by earthchanging activities. As a result, vegetatively lined channels may scour and erode. If storm sewers will be needed, install them before major construction begins.

Ground Cover

Vegetative Stabilization Techniques

Grass and legumes are the most commonly used plant materials for stabilizing slopes. Vegetation is usually established in one of three ways.

Hydroseeding

A mixture of seeds, fertilizer, and water is sprayed on the slope. A mulch and a mulch tacking agent should also be applied. Hydroseeding is effective on large areas.

Standard seeding

Seed is drilled or broadcast either mechanically or by hand. A cultipacker or similar tool is used after seeding to compact the seedbed and cover the seed. The proper timing of seeding, mulching, and watering is important for areas seeded in this manner.

Sodding

Sod strips are laid on the slope and in this way instant cover is provided. Sod should be placed on a prepared bed and pegged on steep slopes. Water and fertilizer are important. This method is effective and is often used on steep slopes and waterway channels.

Suitable soil, good seedbed preparation, and adequate water, lime, and fertilizer are “musts” for all these methods.

Immediately after rough grading is completed, exposed slopes should be temporarily stabilized. If final grading will be delayed, temporary seeding and mulching may be used for short period of protection.

As soon as slopes are brought to final grade, permanent vegetation should be planted.

Maintenance will consist primarily of mowing, fertilizing, liming, and watering. It should be scheduled on a regular basis. Reseed bare areas as necessary.

Mulches

Mulch is usually used after permanent seeding, but may be used before seeding to protect exposed areas for short periods. Mulches protect the soil from the impact of falling rain, slow the velocity of runoff, and increase the capacity of the soil to absorb water. Mulches hold seed in place, preserve soil moisture, and insulate germinating seeds from the extremes of heat and cold.

Many types of mulch are available; such as straw, woodchips, and excelsior mats. Most mulches must be anchored, using plastic emulsions or jute, fiberglass, or plastic netting.

Vegetative Buffer Strips

Sediment can be reduced by maintaining a natural vegetative buffer or filter strip at the base of a slope and by placing sod strips at intervals across the face of the slope. These measures help to slow runoff and trap sediment.

Potential Problems

Some of the problems that arise when a site is developed are high watertable, flood-prone areas, seepage, or adverse soil conditions. If such problem areas are recognized early, site plans can be developed to accommodate, not aggravate, them.

Flood Plains

Is the proposed development located in a flood plain? A Soil Survey report can be used to locate areas subject to flooding by stream overflow. For example, soils such as those in the Hadley or Podunk series would be described as “subject to flooding.” The maps in soil survey reports show the location of such soils.

If a Flood Hazard Analysis has been performed for the town, it may be used to locate flood hazard areas.

If neither of the above are available, a rough identification of flood hazard areas may be accomplished by interviewing local residents, checking town records. Field checks of vegetative cover types, soil moisture, or vertical distance above stream level help point out susceptible areas.

Effect of Development on Surface Runoff

Development usually results in the increase of hard-surfaced, impervious areas, which can increase flooding downstream. These effects may be reduced through:

Minimum lot sizes

For example, the runoff from a subdivision of one-quarter acre lots for a two-year frequency storm can be 50% greater than that from the same subdivision with one-acre lots.

Preservation of the natural drainage pattern

Development may disrupt drainage paths that have developed over hundreds of years. The existing, natural drainageways usually have sufficient capacity for the runoff from all except major, infrequent storm events; unless there has been significant change in the cover conditions upstream.

Stormwater Retarding Structures

Often it is not feasible to preserve enough of the natural drainage and vegetative cover to prevent an increase in runoff. A properly designed retarding structure temporarily stores runoff from a developed area and releases the water over a period of time, at a rate within the capacity of the channel downstream

Adverse Soil Conditions

Large Rocks and Ledge

If these are encountered, development costs rise significantly. Plan the development around these conditions and leave rocks and ledge undisturbed if possible.

Settlement Potential

Fills placed on soft organic soils or located in wet areas tend to settle unless care is taken to see that they are properly constructed. Foundations for larger buildings are usually designed by a soils or foundations engineer, but plans for houses, parking lots, driveways may not have been developed with sufficient concern for possible foundation settlement.

Water Table

Areas with a high water table should either be avoided or steps taken to drain or otherwise control the condition. High water table can cause malfunctioning septic systems, damp basements, uneven foundation settlement.

Seepage

Seepage may be encountered at the base of a hill (where the ground surface flattens out); or on a slope, where a roadside cut or an excavation for a foundation is made. Houses, driveways, roads, parking lots, etc., located in such areas usually require drainage measures.

Cuts and Fills

Constructed cuts and fills tend to change site characteristics (drainage, soil materials, stability, etc.). The earth-moving involved raises development costs. A comparison should be made of the cost of doing such work, and the subsequent drainage measures required vs. working with the natural ground contours to minimize cuts and fills. The comparison may show the latter to be more economical; as well as more pleasing to the eye.

Stabilization Principles for Site Development

Review and consider all existing conditions in the initial site selection for the project. Select a site that is suitable rather than force the terrain to conform to development needs. Ensure that development features follow natural contours. Steep slopes, areas subject to flooding, and highly erodible soils severely limit a site's use, while level, well-drained areas offer few restrictions. Control seepage and high water table conditions. Any modification of a site's drainage features or topography requires protection from erosion and sedimentation.

Keep Disturbed Areas Small

Careful site selection will help on this point. The site, or corridor, should be able to accommodate the development with a minimum of grading.

The development plan should fit its topographic, soil, and vegetative characteristics with a minimum of clearing and grading. Natural cover should be retained and protected wherever possible. Critically erodible soil, steep slopes, streambanks, and drainageways should be identified. The development can then be planned to disturb these vulnerable areas as little as possible.

Where earth change and removal of vegetation are necessary, keep the area and duration of exposure to a minimum. Plan the phases of development so that only areas which are actively being developed are exposed. All other areas should have a good cover of vegetation or mulch.

Stabilize and Protect Disturbed Areas as Soon as Possible

Two methods are available for stabilizing disturbed areas: mechanical (or structural) methods and vegetative methods. In some cases, both are combined in order to retard erosion.

Keep Stormwater Runoff Velocities Low

The removal of existing vegetative cover during development and the resulting increase in impermeable surface area after development will increase both the volume and velocity of runoff. These increases must be taken into account when providing for erosion control.

Protect Disturbed Areas from Stormwater Runoff

Best management practices can be utilized to prevent water from entering and running over the disturbed area. Diversions and other control practices intercept runoff from higher watershed areas, store or divert it away from vulnerable areas, and direct it toward stabilized outlets.

Retain Sediment within the Corridor or Site Area

Sediment can be retained by two methods: filtering runoff as it flows and detaining sediment-laden runoff for a period of time so that the soil particles settle out. The best way to control sediment, however, is to prevent erosion.

After construction is completed, inspection and maintenance are vital to the performance of erosion and sedimentation control measures. If not properly maintained, some practices may cause more damage than they prevent.

When considering which control measure to use, always evaluate the consequences of a measure failing. Failure of a practice may be hazardous or damaging to both people and property. For example, a large sediment basin failure can have disastrous results; low points in dikes can allow them to overflow and cause major gullies a fill slope.

It is essential to inspect all practices to determine that they are working properly and to ensure that problems are corrected as soon as they develop. Provide some means to see that routine checks of operating erosion and sedimentation control practices are carried out after construction is over.

Developing An Erosion and Sediment Control Plan

An erosion and sedimentation control plan should serve as a blueprint for the location, installation, and maintenance of practices to control all anticipated erosion, and prevent sediment from leaving the site.

Tracts of land vary in suitability for development. Knowledge of the soil type, topography, natural landscape values, drainage patterns, flooding potential, and other pertinent data helps identify both beneficial features and potential problems of a site. Developers and builders can minimize erosion, sedimentation, and other construction problems by selecting areas appropriate for the intended use.

The erosion and sedimentation control plan should be a part of the general construction contract. It should show location, design, and construction schedule for all erosion and sedimentation control practices. Also, developers and builders must abide by the local town bylaws.

Contents

An erosion and sedimentation control plan must contain sufficient information to describe the site development and the system intended to control erosion and prevent off-site damage from sedimentation. At a minimum, the plan should contain the following items:

- Brief narrative,
- Vicinity map,
- Site topography map,
- Site development plan,
- Erosion and sedimentation control plan drawing,
- Detail drawings and specifications,
- Vegetation plan,
- Supporting calculations,
- Construction sequence,
- Maintenance plan.

The narrative will clarify details of the plan as an aid for the inspector and the contractor. The narrative should be concise, but should describe:

- Nature and purpose of the proposed development,
- Pertinent conditions of the site and adjacent areas, and
- Proposed erosion and sedimentation control measures.

The narrative should also include how the developer has incorporated applicable regulations (e.g. filed wetlands NOI, applied for an NPDES Storm Water Permit, etc.)

The designer should assume that the plan reviewer has not seen the site and is unfamiliar with the project. Map scales and drawings should be appropriate for clear interpretation.

There is an example erosion and sedimentation control plan in a later section.

Data Collection and Preliminary Analysis

The base map for the erosion control plan is prepared from a detailed topographic map. A soils map may be obtained from the local Conservation District office. Transferring soil survey information to the topographic map is helpful for site evaluation. Inspect the site to verify the base map with respect to natural drainage patterns, drainage areas, general soil characteristics, and off-site factors.

The base map should reflect such characteristics as:

- Soil type and existing contours,
- Natural drainage patterns,
- Unstable stream reaches and flood marks,
- Watershed areas,
- Existing vegetation,
- Critical areas such as steep slopes, eroding areas, rock out-croppings, and seepage zones,
- Unique or noteworthy landscape values to protect,
- Adjacent land uses; especially areas sensitive to sedimentation or flooding,
- Critical or highly erodible soils that should be left undisturbed.

Base map should include:

Scale
North arrow
Benchmark
Property boundaries
Lot lines

Use the base map to locate:

- Buffer zones,
- Suitable stream crossing areas,
- Access routes for construction and maintenance of sedimentation control devices,
- Borrow and waste disposal areas, and
- The most practical sites for control practices.

Analysis of the topography, soils, vegetation, and hydrology will help the planners and designers to recognize the limitations of the site, and identify locations suitable for development.

Preparing the Plan

The erosion and sedimentation control plan should seek to protect the soil surface from erosion, control the amount and velocity of runoff, and capture sediment on-site during each phase of the construction project:

Schedule activities

Coordinate installation of erosion and sediment control practices with construction activities.

Sediment control practices should precede grading activities.

Protect the soil surface

Limit the extent of disturbance. Stabilize the soil surface immediately. Once the surface has been disturbed, it is vulnerable to erosion and should be protected with appropriate cover, such as mulch or vegetation.

Control surface runoff

Divert water from undisturbed areas to avoid disturbed areas. Break up long slopes with temporary diversions to reduce the velocity of runoff. Divert sediment-laden water to sediment impoundments. Make all outlets and channels stable for the intended flow.

Capture sediment on-site

Divert runoff that transports sediment to an adequate sediment-trapping device to capture sediment on the site.

Preparing the Plan - Step by Step

Runoff-Erosion Analysis

Landscape

Evaluate proposed changes in the landscape to determine their effect on runoff and erosion. Make a note of all physical barriers to surface runoff, such as roads, buildings, and berms. Check slope grades and lengths for potential erosion problems. Designate intended collection points for concentrated flow and specify controls to dissipate energy or stabilize the surface. Designate areas to be protected or used as buffer zones in this phase.

Runoff yield

Evaluate surface runoff for the entire contributing drainage area, both on-site and off-site. Delineate small subwatersheds on-site and estimate peak runoff rates and volumes at selected collection points. Base runoff determinations on site conditions during and after development, not preconstruction conditions.

Sediment yield

Estimate sediment yield by subwatersheds. This aids in identifying preferred locations for sediment traps and barriers and can be used to estimate the expected cleanout frequency. An area that is subject to excessive erosion may need extra storage capacity in traps or additional precautions during construction.

Sediment Control

Erosion control practices reduce the amount of sediment generated, but they do not eliminate the need for sediment control devices such as barriers and traps. Sediment control practices operate by reducing flow velocity and creating shallow pools that reduce the carrying capacity of runoff. Thus sedimentation occurs on-site rather than off-site. Sediment is generally not controlled by filtering, but by deposition. The designer should locate all traps and barriers recognizing that they represent deposition points where access for maintenance will be necessary.

Sediment basins and traps

Select sites and install sediment basins and traps before other construction activities are started. Also, consider locations for diversions, open channels, and storm drains at this time so that all sediment-laden runoff can be directed to an impoundment structure before leaving the construction site.

Divert sediment-free water away from sediment basins and release it through stable outlets. This reduces construction costs and improves basin efficiency.

The plan should show access points for cleanout of all traps and basins and indicate sediment disposal areas. Maintenance of storage capacity is essential throughout the construction period.

Sediment fences

Sediment fences provide effective control of sediment carried in sheet flow. They are particularly useful where there is limited space to work such as near property lines, among trees, or near sidewalks or streets. Sediment fences should never be used across streams, ditches, channels, or gullies.

A sediment fence operates by reducing flow velocity and causing a shallow pool to form. If filtering action is required, the designer should assume that the barrier will clog rapidly so that all runoff must be retained behind the fence or released through a designated outlet. Any outlet points must be reinforced and stabilized and should be designated in the plan.

Place sediment fences on relatively flat ground with sufficient area for a pool to develop without putting unnecessary strain on the fence. If a level area is not available at the fence location, excavate a trench directly upslope from the fence.

Show sediment fences on the plan and indicate deposition areas and needed overflow or bypass outlet points. Also show access routes for maintenance.

Inlet protection

Inlet protection devices for storm sewers, conduits, slope drains, or other structures make effective, low-cost deposition areas for trapping and holding sediment. A shallow excavation in conjunction with a sediment barrier can be effective at many locations. Show where these measures will be located, what type of device will be used, and how these devices will be constructed and maintained.

Protection of Disturbed Areas

Once an area is disturbed, it is subject to accelerated erosion. In the plan, show how erosion will be controlled on these disturbed areas. Erosion control can be achieved by:

- Limiting the size of clearing and time of exposure by proper scheduling,
- Reducing the amount of runoff over the disturbed surface,
- Limiting grades and lengths of slopes, and
- Reestablishing protective cover immediately after land-disturbing activities are completed or when construction activities are delayed for 30 or more working days.

Cut-and-fill slopes

Steep cut or fill slopes are particularly vulnerable to erosion. Protect by installing temporary or permanent diversions just above the proposed slope before it is disturbed. Provide a stable channel, flume, or slope drain, where it is necessary to carry water down a slope. Flow channels may be either vegetated, lined with stone, or paved, or a combination - depending on slope and soil conditions.

Shorten long slopes by installing temporary diversions across the slope to reduce flow velocity and erosion potential. Install permanent diversions with slope drains and protected outlets on long steep slopes (over 20%) as the slopes are constructed.

Finish final slope grades without delay and apply surface stabilization measures as soon as possible. Roughen slope surfaces to improve the success of vegetative stabilization. Consider both the stabilization measures and how they will be maintained before planning the steepness of the finish slope. For example, if the finished slope is to have grass cover that will be mowed, it should be constructed on a grade of 3:1 or flatter.

Surface covers

Riprap, gravel, straw and other cover materials can provide immediate surface protection to disturbed soil areas. Riprap is especially useful where concentrated runoff occurs over steep slopes. Riprap should be installed on a gravel or filter fabric bed.

Construction traffic

Construction roads, parking areas, and construction access routes need to be carefully planned. Ensure that traffic patterns follow site contours and limit the length of routes up steeper slopes. Generally, road grades should not exceed 12%.

Controlling surface runoff is necessary to prevent serious roadside erosion. Proper grading of the road surface, stable channel design, and use of water bars, other diversions, and culverts help prevent erosive flows.

Where water tables are high, subsurface drainage may be needed to stabilize the subgrade. Storm drains should be considered for water disposal where channel grade exceeds 5%. Plans should show all stabilization measures needed to control surface runoff from all roads.

Borrow areas and disposal areas

Clear only as needed, and protect from surface runoff. Maintain berms as fill slopes are constructed to reduce slope length and control runoff. Slope all areas to provide positive drainage, and stabilize bare soil surfaces with permanent vegetation or mulch as soon as final grades are prepared. Direct all runoff that contains sediment to a sediment-trapping device. In large borrow and disposal sites, shape and deepen the lower end to form an in-place sediment trap, if site conditions warrant it.

Utilities

Use the spoil from utility trench excavations to divert flow from upslope areas (but use care in spoil placement to avoid blocking natural surface outlets). Diversions and water bars can reduce erosion when properly spaced across utility rights-of-way.

When utilities are located near a stream, maintain an undisturbed buffer zone wherever possible. If site dewatering is necessary, pump or divert muddy water to sediment traps or sump pits before discharging it to the stream. If streams must be crossed, make sure all necessary materials and equipment are on-site before construction begins, and complete work quickly. Finish all disturbed surfaces to design grade and immediately stabilize them with permanent vegetation or other suitable means. Where utilities cross the stream, specify measures to prevent sedimentation.

Perimeter protection

Consider diversion dikes for perimeter protection for all proposed developments and install them where appropriate before clearing the site. Exercise care not to create flooding or erosion by blocking the natural drainage pattern. Be sure to provide an adequate outlet.

Dust control

Exposed soil surfaces that are nearly level have little potential for runoff erosion but may be subject to severe wind erosion. Keeping the disturbed surface moist during windy periods is an effective control measure, especially for construction haul roads.

Preserving vegetation

Preserve existing vegetation on the site as long as possible as a cost-effective way to prevent on-site erosion and off-site sedimentation.

Runoff Conveyance

The safe conveyance of runoff water from a construction site is achieved by: utilizing and supplementing existing stable watercourses, designing and constructing stable open channels, or installing storm drains with stable outlets. The plan should indicate locations and designs for these facilities. Complete and stabilize outlets for channels, diversions, slope drains, or other structures before installing the conveyance measure.

Contact the local Conservation Commission regarding any stream crossing or other work conducted in a wetland resource area. The Massachusetts Wetland Protection Act requires that the proponent file a “Request for Determination of Applicability” or “Notice of Intent.”

Existing watercourses

When using existing watercourses, either show that flow velocities are acceptable for increased runoff conditions or indicate how necessary stabilization will be achieved.

Excavated channels

When channels are to be excavated, the design should be prepared by a professional engineer. Include calculations in the plan documentation.

Wide, shallow channels with established grass linings are usually stable on slopes up to 5%. These channels must be protected with temporary liners until grass is established. If channel gradients are too steep to use vegetation, riprap or concrete linings may be required. In some instances grade stabilization structures may be needed.

Storm drains

Where the site plan calls for a system of storm drains, the drains may be used effectively in the erosion and sedimentation control plan. Build junction boxes or inlets early in the construction sequence, and grade the adjacent area to drain toward the inlet. Install an inlet protection device at all open pipe inlets and excavate a shallow basin in the approach to the inlet for sediment storage.

The storm drain flow from the protected inlets may be diverted to a sediment basin for additional sediment control. Restrict the drainage area for inlets to less than one acre. Inspect inlet protection devices frequently for needed maintenance.

Stream Protection

Streambanks, streambeds, and adjoining areas are susceptible to severe erosion if not protected. Include sufficient detail to show that streams are stable for the increased velocities expected from the development activity. At a minimum, all streams should be stable for flows from the peak runoff from the 10-year storm.

Contact the local Conservation Commission regarding any stream crossing or other work conducted in a wetland resource area. The Massachusetts Wetland Protection Act requires that the proponent file a “Request for Determination of Applicability” or “Notice of Intent.”

When stability analysis shows that the stream requires protection, vegetation is usually the preferred approach because it maintains the stream nearest to its natural state. When flow velocities approach 4-6 feet per second, or if frequent periods of bankful flows are expected; structural measures such as riprap lining or grade stabilization structures are usually necessary. In the plan, show where stream protection is needed and how it will be accomplished.

Runoff into stream

Only sediment-free runoff may be discharged from construction sites directly into streams. Ensure that all other flows enter from desilting pools formed by sediment traps or barriers.

Velocity control

Keep the velocity of flow discharged into a stream within acceptable limits for site conditions. Control velocity by installing an appropriate outlet structure.

Buffer zone

Areas adjoining streams should be left undisturbed as buffers. Existing vegetation, if dense and vigorous, will reduce flow velocities and trap sediment from sheet flow. However, the principal benefit of leaving natural buffer zones along streams is that they prevent excessive erosion in these sensitive areas. Maintaining stream canopies also protects fish and wildlife habitats; provides shade, windbreaks, and noise barriers, protects the bank from out-of-bank flood flows; and generally preserves natural site aesthetics.

Indicate stream buffer zones in plans that involve natural streams. The width is determined by site conditions but generally should not be less than 25 feet on each side of the stream. If natural buffers are not available, provide artificial buffers.

Off-site stream protection

Increased rate and volume of runoff from development activities may cause serious erosion at points some distance downstream. The developer should work with downstream property owners to stabilize sensitive downstream channel areas.

Stream crossing

Minimize the number of stream crossings. Construct crossings during dry periods. If necessary, divert water during construction. The plan should show the type of crossing to be used and the associated control measures to minimize erosion from surface runoff such as diversions, outlet structures, riprap stabilization, etc.

Construction Scheduling

Appropriate sequencing of construction activities is an effective means for controlling erosion and sedimentation. Use the construction schedule of the general contract as part of the erosion and sedimentation control plan. Install the primary erosion and sedimentation control practices for the site, i.e. sediment basins and traps, and a water conveyance system before undertaking major land-disturbing activities. Schedule work with an eye to the calendar, to minimize impacts due to seasonal changes.

Install sediment basins and primary sedimentation control practices as the first structural measures. Next install the overall water disposal outlet system for the site.

Stabilize all construction access routes, including construction entrances and exits, and the road drainage system, as the roads are constructed. Install storm drains early in the construction sequence and include them in the sedimentation control plan. Install inlet protection devices for efficient sediment control around the inlets. This allows early use of the inlets and the drain system.

Install diversions above areas to be disturbed and, where needed, along boundaries of areas to be graded before grading takes place.

After all principal erosion and sedimentation control measures are in place, perform the land clearing and rough grading. Clear areas only as needed and complete final grading and surface stabilization as soon as possible. Minimize the time of exposure and select temporary ground cover according to the location and season. Temporary surfaces should be stabilized as soon as active grading is suspended, regardless of the time of year. Disturbed areas should be revegetated early enough in the autumn that good cover is established before cold weather comes.

Construction Scheduling - EPA Baseline General Permit Requirements for Site Stabilization:

Except as provided in the paragraphs below, stabilization measures shall be initiated as soon as practicable in portions of the site where construction activities have temporarily or permanently ceased, but in no case more than 14 days after the construction activity in that portion of the site has temporarily or permanently ceased.

(a) Where the initiation of stabilization measures by the 14th day after construction activity temporary or permanently cease is precluded by snow cover, stabilization measures shall be initiated as soon as practicable.

(b) Where construction activity will resume on a portion of the site within 21 days from when activities ceased (e.g. the total time period that construction activity is temporarily ceased is less than 21 days), then stabilization measures do not have to be initiated on that portion of site by the 14th day after construction activity temporarily ceased

Inspection and Maintenance

In the erosion and sedimentation control plan, indicate who is responsible for maintenance and when it will be provided. The maintenance schedule should be based on site conditions, design safeguards, construction sequence and anticipated weather conditions. Specify the amount of allowable sediment accumulation, design cross-section, and, required freeboard for each practice and what will be done with the sediment removed. The plans should also state when temporary practices will be removed and how these areas and waste disposal areas will be stabilized.

Inspection Program

Essential parts of an inspection program include:

· Inspection during or immediately following initial installation of sediment controls.

· Inspection following severe rainstorms to check for damage to controls.

· Inspection prior to seeding deadlines, particularly in the fall.

· Final inspection of projects nearing completion to ensure that temporary controls have been removed, stabilization is complete, drainageways are in proper condition, and that the final contours agree with the proposed contours on the approved plan.

In addition, interim inspections should be made as manpower and workload permit, giving particular attention to the maintenance of installed controls.

All inspections should be documented by a written report or log. These reports should contain the date and time of inspections, dates when land-disturbing activities begin, comments concerning compliance or noncompliance and notes on any verbal communications concerning the project.

Before Construction

An on-site preconstruction meeting involving the owner, contractor, and erosion control personnel is recommended. This allows all parties to meet, review the plans and construction schedule, and agree on responsibility and degree of control expected. Discuss maintenance requirements, phasing of operations, and plan revisions. The preconstruction meeting is especially important for large, complex jobs or when the contractor and/or developer has had little experience in this type of work.

During Construction

The developer may be held responsible for off-site sediment damage resulting from construction activities even though an approved plan has been properly installed and maintained. Therefore, inspect the property boundary frequently for evidence of sedimentation.

It may be necessary to modify the erosion and sediment control plan during construction to account for unanticipated events or construction changes.

During Construction

In addition to the inspection and maintenance reports, the operator should keep records of the construction activity on the site, including:

· Dates when major grading activities occur in a particular area.

· Dates when construction activities cease in a particular area, temporarily or permanently.

· Dates when a particular area is stabilized, temporarily or permanently.

After Construction

Items to consider after construction is completed include permanent stabilization once activities have ceased, removal of temporary structural measures, final inspection, and maintenance of permanent structures.

References

Lobdell, Raymond, *A Guide to Developing and Re-Developing Shoreland Property in New Hampshire*, North Country Resource Conservation and Development Area, Inc., Meredith, NH, 1994.

Massachusetts Department of Environmental Protection, Office of Watershed Management, Nonpoint Source Program, *Massachusetts Nonpoint Source Management Manual*, Boston, Massachusetts, June, 1993.

Minnesota Pollution Control Agency, Division of Water Quality, *Protecting Water Quality in Urban Areas, Best Management Practices for Minnesota*, ________ , MN, October, 1989.

Minnick, E. L., and H. T. Marshall, *Stormwater Manageement and Erosion Control for Urban and Developing Areas in New Hampshire*, Rockingham County Conservation District, August 1992.

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Schueler, Thomas R., *Controlling, Urban Runoff: A Practical Manual for Planning and Designing Urban BMPs*, Metropolitan Washington Council of Governments, Washington, DC, July, 1987.

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Tourbier, J., and R. Westmacott, Water Resources Center, University of Deleware, *Water Resources Protection Measures in Land Development - A Handbook*, Newark, Del., April, 1974.

U. S. Environmental Protection Agency, *Guidance Specifying Management Measures For Sources Of Nonpoint Pollution In Coastal Waters*, EPA-840-B-92-002, Washington, DC, January, 1993.

Washington State Department of Ecology, *Stormwater Management Manual for the Puget Sound Basin, Olympia*, WA, February, 1992.

Best Management Practice Selection

On any construction site the objective in erosion and sediment control is to prevent off-site sedimentation damage. Four basic methods are used to control erosion on construction sites: planning, soil stabilization, runoff control and sediment control. Careful site analysis, planning and scheduling can reduce the need to utilize stabilization and control practices, and, thereby, reduce the cost of implementing these measures.

Identify Control Problem

Controlling erosion should be the first line of defense. Controlling erosion is very effective for small disturbed areas such as single lots or small areas of a development that do not drain to a sediment-trapping facility. Where soil properties and topography of the site make the design of sediment trapping facilities impractical, runoff control and soil stabilization should be used.

Sediment trapping facilities should be used on large developments where mass grading is planned, where it is impossible or impractical to control erosion, and where sediment particles are relatively large. A combination of erosion control and sedimentation control measures is usually the least expensive way to accomplish erosion and sediment control.

Identify Problem Areas

Areas where erosion is to be controlled usually involve slopes, graded areas or drainage ways. Slopes include graded rights-of-way, stockpile areas, and all cut or fill slopes. Graded areas include all stripped areas other than slopes. Drainage ways are areas where concentrations of water flow naturally or artificially. Problem areas that need sediment control can be either large or small.

Identify Required Strategy

Select the strategy to solve the problem. Strategies can utilize an individual practice or a combination of practices. For example, if there is a cut slope to be protected from erosion, the strategies may be to protect the ground surface, divert water from the slope or shorten it. Any combination of the above can be used. If no rainfall except that which falls on the slope has the potential to cause erosion, and if the slope is relatively short, protecting the soil surface may be all that is required to solve the problem.

Select Specific Control Measures

The tables on the following pages are guides for selecting erosion and sediment control practices. This material can be used by either designers and developers or by plan review agencies.

The practices chosen for a site will often vary from one individual to another, depending on individual judgement and preference, past experience with a conservation practice, and the practices' suitability for a particular site. Persons reviewing an erosion and sedimentation control plan should not expect to find one set of "predetermined practices" used. The reviewer can, however, refer to these tables: (a) as an aid in recognizing potential problem areas that may exist at a site, and (b) for guidance to see if the developer and designer have addressed the potential problems.

SITE WORK: On-site Roads, Controlling Road Runoff

ITEM	RECOMMENDED PRACTICES
Site Preparation	Preserving Natural Vegetation Construction Entrance Construction Road Stabilization Filter Berm
Surface Stabilization	Temporary Seeding Mulching Riprap
Runoff Control	Temporary Diversions Water Bars Sump Pit
Runoff Conveyance	Grassed Waterway (Slopes up to 5%) Lined Waterway Temporary Slope Drain Paved Flume Vegetated Swale Inlet Protection Outlet Protection and Stabilization
Other	Dust Control

(Note: The structural practices listed above are suitable for slopes of up to 12%, except as noted. Steeper slopes usually need special consideration.)

Clearing and Grading

ITEM	RECOMMENDED PRACTICES
Site Preparation	Preserving Natural Vegetation Construction Entrance Land Grading
Surface Stabilization	Surface roughening Terrace Topsoiling Temporary Seeding Permanent Seeding Mulching Riprap
Runoff Control	Temporary Diversion Permanent Diversion Terrace Water Bar Sump Pit
Outlet Protection	Outlet Protection and Stabilization Level Spreader
Runoff Conveyance	See Storm Runoff sheet
Sediment Traps and Barriers	See Sediment Control sheet
Other	Dust Control

Excavations, Stockpiles, & Debris Disposal

ITEM	RECOMMENDED PRACTICES
Surface Stabilization	Surface roughening Topsoiling Temporary Seeding Permanent Seeding Trees and Shrub Planting Mulching
Runoff Control	Temporary Diversion
Sediment Traps and Barriers	Sediment Trap Sediment Fence
Other	Dust Control

Rill and Gully Erosion

ITEM	RECOMMENDED PRACTICES
Runoff Control	Temporary Diversion Permanent Diversion Water Bar Buffer Zone
Runoff Conveyance	Riprap-lined Channel Lined Waterway Temporary Slope Drain Paved Flume
Outlet Protection	Outlet Protection and Stabilization Level Spreader
Surface Stabilization	Slope Stabilization Topsoiling Surface Roughening Temporary Seeding Permanent Seeding Mulching Riprap Tree and Shrub Planting

Sediment Control

(Measures should be installed before major land disturbance begins)

ITEM	RECOMMENDED PRACTICES
Disturbed areas of less than 2 acres	Sediment Trap Sediment Fence Filter Berm Brush Barrier (Drainage area up to ¼ acre) Filter Strip Straw or Hay Bale Barrier Silt Curtain
Disturbed areas, 2-5 acres	Sediment Trap Sediment Basin Filter Strip Rock Dam Silt curtain
Disturbed areas of more than 5 acres	Sediment Basin Rock Dam Silt Curtain
Other	Dust Control

Storm Runoff

ITEM	RECOMMENDED PRACTICES
Drainage area less than 20 acres	
Runoff Control	Temporary Diversion Permanent Diversion Water Bar
Runoff Conveyance	Grassed Waterway (Slopes up to 5%) Vegetated Swale Lined waterway Riprap-lined Channel Temporary Slope Drain Paved Flume Inlet Protection
Outlet Protection	Level Spreader (Drainage up to 5 acres) Outlet Protection and Stabilization

Drainage area more than 20 acres

Same as above, except in addition, the designer would normally perform hydrologic and hydraulic calculations showing that runoff, during and after construction of the project, would comply with permitting agency requirements.

Streambank Protection and Stabilization

ITEM	RECOMMENDED PRACTICES
Design velocity less than 6 feet per second	Vegetative Methods Soil Bioengineering Methods Structural Methods
Design velocity more than 6 feet per second	Soil Bioengineering Methods Structural Methods

(Note: Contact the local Conservation Commission regarding any work conducted in what may be a wetland resource area. The Massachusetts Wetland Protection Act requires that the proponent file a “Request for Determination of Applicability” or “Notice of Intent.”)

Stream Crossings

ITEM	RECOMMENDED PRACTICES
Temporary	
To move equipment	Stream Crossing, Temporary
Surface Stabilization	Temporary Seeding Mulching Riprap
Permanent	
Vehicular traffic,To move Equipment	Permanent Stream Crossing; e.g. Bridge or Culvert
Surface Stabilization	Permanent Seeding Mulching Riprap

(Note: Contact the local Conservation Commission regarding any work conducted in what may be a wetland resource area. The Massachusetts Wetland Protection Act requires that the proponent file a "Request for Determination of Applicability" or "Notice of Intent.")

Building Construction, Utilities Installations

ITEM	RECOMMENDED PRACTICES
Surface Stabilization	Surface Roughening Topsoiling Temporary Seeding Permanent Seeding Mulching Tree and Shrub Planting
Runoff Control	Temporary Diversion Water Bar Sump Pit
Sediment Control	Sediment Trap Sediment Fence Filter Strip
Other	Construction Road Stabilization Dust Control

Special Site Problems

ITEM	RECOMMENDED PRACTICES
Seepage areas or high water table	Subsurface Drainage Sump Pit
Unstable temporary channels	Check Dam Riprap-lined Channel
Unstable permanent channels	Riprap-lined Channel Lined Waterway Grade Stabilization Structure
Blowing dust or sand	Dust Control Sand Fence
Dune reinforcement and stabilization	Sand Dune and Sandblow Stabilization Sand Fence

(Note: Contact the local Conservation Commission regarding any work conducted in what may be a wetland resource area. The Massachusetts Wetland Protection Act requires that the proponent file a “Request for Determination of Applicability” or “Notice of Intent.”)

Final Site Stabilization

ITEM	RECOMMENDED PRACTICES
Surface Stabilization	Surface roughening Terrace Topsoiling Permanent Seeding Sodding Trees and Shrub Planting Mulching Riprap
Runoff Control	Permanent Diversion
Runoff Conveyance	Grassed Waterway Vegetated Swale Lined Waterway Riprap-lined Channel Paved Flume
Outlet Protection	Level Spreader Outlet Protection and Stabilization
Inlet Protection	Sod Drop Inlet Protection, or permanent paving

References

Connecticut Council on Soil and Water Conservation, ***Connecticut Guidelines for Soil Erosion and Sediment Control***, Hartford, CT, January, 1985.

New York Guidelines for Urban Erosion and Sediment Control, March 1988.

North Carolina Sediment Control Commission, ***Erosion and Sediment Control Planning and Design Manual,*** Raleigh, NC, September, 1988.

Practices

Brush Barrier

Buffer Zones, Stream Corridors, and Riparian Areas

Check Dam

Construction Entrance

Construction Road Stabilization

Diversion, Permanent

Diversion, Temporary

Dust Control

Filter Berm

Filter Strip, vegetated

Flume, paved

Gabions

Geotextiles

Grade Stabilization Structure

Inlet Protection

Land Grading

Level Spreader

Mulching & Netting

Outlet Protection & Stabilization

Preserving Natural Vegetation

Brush Barrier

A temporary sediment barrier constructed at the perimeter of a disturbed area, using residue materials available from clearing and grubbing on-site.

Used to intercept and retain sediment from limited disturbed areas.

Where Practice Applies

Below disturbed areas of less than one quarter acre that are subject to sheet and rill erosion, where enough residue material is available for construction of such a barrier. Note: This does not replace a sediment trap or pond.

Advantages

- Brush barriers can often be constructed using materials found on-site.

Planning Considerations

Organic litter and spoil material from site clearing operations is usually hauled away to be disposed of elsewhere. Much of this material can be used effectively on the construction site itself. During clearing and grubbing operations, equipment can push or dump the mixture of limbs, small vegetation, and root mat along with minor amounts of soil and rock into windrows along the toe of a slope where erosion and accelerated runoff are expected.

Because brush barriers are fairly stable and composed of natural materials, maintenance requirements are small. Material containing large amounts of wood chips should not be used because of the potential for leaching from the chips.

Design Recommendations

Height - 3 feet maximum.

Width - 5 to 15 feet at base.

Filter fabric anchored over the berm will enhance its filtration capacity.

Maintenance

Brush barriers generally require little maintenance. Heavy deposits of sediment may need removal. Occasionally, tearing of the filter fabric may occur.

When the barrier is no longer needed the fabric can be removed to allow natural establishment of vegetation within the barrier. The barrier will rot over time.

Practices

References

Washington State Department of Ecology, ***Stormwater Management Manual for the Puget Sound Basin***, Olympia, WA, February, 1992.

Buffer Zones, Stream Corridors, and Riparian Areas

An undisturbed area or strip of natural vegetation or an established suitable planting that will provide a living filter to reduce soil erosion and runoff velocities.

Where Practice Applies

Natural buffer zones are used along streams and other bodies of water that need protection from erosion and sedimentation. Vegetative buffer zones can be used to protect natural swales and incorporated into natural landscaping of an area.

Advantages

Buffer zones provide critical habitat adjacent to streams and wetlands, as well as assist in controlling erosion, especially on unstable steep slopes. Buffers along streams and other water bodies also provide wildlife corridors, a protected area where wildlife can move from one place to another.

- Buffer zones act as a visibility and noise screen, and provide aesthetic benefits.
- Low maintenance requirements.
- Low cost when using existing vegetation.

Disadvantages/Problems

Extensive buffers will increase development costs.

Planning Considerations

- Preserving natural vegetation or plantings in clumps, blocks, or strips is generally the easiest and most successful method.
- Establishing new buffer strips requires the establishment of a good dense turf, trees, and shrubs. Careful maintenance is important to ensure healthy vegetation. The need for routine maintenance such as mowing, fertilizing, liming, irrigating, pruning, and weed and pest control will depend on the species of plants and trees involved, soil types, and climatic conditions.

- Leave all unstable steep slopes in natural vegetation.
- Fence or flag clearing limits and keep all equipment and construction debris out of the natural areas.
- Keep all excavations outside the dripline of trees and shrubs.
- Do not push debris or extra soil into the buffer zone area because it will cause damage from burying and smothering.

References

U. S. Environmental Protection Agency, ***Storm Water Management For Construction Activities,*** EPA-832-R- 92-005, Washington, DC, September, 1992.
Washington State Department of Ecology, ***Stormwater Management Manual for the Puget Sound Basin, Olympia***, WA, February, 1992.

Check Dam

A check dam is a small dam constructed across a drainage ditch, swale, or channel to lower the speed of flow. Reduced runoff speed reduces erosion and gullying in the channel and allows sediments to settle out.

A check dam may be built from stone, sandbags filled with pea gravel, or logs.

Purpose

To reduce flow velocity: reducing erosion of the swale or ditch, and allowing retention of sediments.

Where Practice Applies

Where temporary channels or permanent channels are not yet vegetated, channel lining is infeasible and velocity checks are required.

This practice may be used as a temporary or emergency measure to limit erosion by reducing flow in small open channels.

This practice should be used with drainage areas of 2 acres or less.

Check dams may be used:

- To reduce flow in small temporary channels that are presently undergoing degradation,
- Where permanent stabilization is impractical due to the temporary nature of the problem, and
- To reduce flow in small eroding channels where construction delays or weather conditions prevent timely installation of non-erosive liners.

Advantages

- Inexpensive and easy to install.
- Reduce velocity and may provide aeration of the water.
- Check dams not only prevent gully erosion from occurring before vegetation is established, but also cause a high proportion of the sediment load in runoff to settle out.
- In some cases, if carefully located and designed, these check dams can remain as permanent installations with very minor regrading, etc. They may be left as either spillways, in which case accumulated sediment would be graded and seeded, or as check dams to capture further sediment coming off that site.

Disadvantages/Problems

- Because of their temporary nature, many of these measures are unsightly, and they should be removed or converted to permanent check dams before dwelling units are rented or sold.
- Removal may be a significant cost depending on the type of check dam installed.
- Check dams are only suitable for a limited drainage area.
- May kill grass linings in channels if the water level remains high after rainstorms or if there is significant sedimentation.
- Reduce the hydraulic capacity of the channel.
- May create turbulence which erodes the channel banks.
- Clogging by leaves in the fall may be a problem.

Planning Considerations

Check dams are usually made of stone. The center section must be lower than the edges.

The dams should be spaced so that the toe of the upstream dam is at the same elevation as the top of the downstream dam.

Ensure that overflow areas along the channel are resistant to erosion from out-of-bank flow caused by the check dams.

Check dams can also be constructed of logs, or pea gravel filled sandbags. Log check dams may be more economical from the standpoint of material costs, since logs can often be salvaged from clearing operations. However, log check dams require more time and hand labor to install. Stone for check dams must generally be purchased. This cost is offset somewhat by the ease of installation.

If stone check dams are used in grass-lined channels which will be mowed, care should be taken to remove all the stone from the channel when the dam is removed. This should include any stone which has washed downstream.

Since log check dams are embedded in the soil, their removal will result in more disturbance of the soil than will removal of stone check dams. Consequently, extra care should be taken to stabilize the area when log dams are used in permanent ditches or swales.

Design & Construction Recommendations

Check dams can be constructed of rock, sand bags filled with pea-gravel, or logs. Provide a sump immediately upstream.

The maximum spacing between the dams should be such that the toe of the upstream dam is at the same elevation as the top of the downstream dam.

The rock must be placed by hand or mechanical placement (do not dump rock to form dam) to achieve complete coverage of the ditch or swale and to ensure that the center of the dam is lower than the edges. The rock used must be large enough to stay in place given the expected design flow through the channel.

Log check dams should be constructed of 4 to 6-inch diameter logs embedded into the soil at least 18 inches.

In the case of grass-lined ditches and swales, check dams shall be removed when the grass has matured sufficiently to protect the ditch or swale unless the slope of the swale is greater than 4 percent. The area beneath the check dams shall be seeded and mulched immediately after dam removal.

Common Trouble Points

Stone displaced from face of dam
Stone size too small and/or face too steep.

Erosion downstream from dam
Provide stone-lined apron.

Erosion of abutments during high flow
Rock abutment height inadequate.

Sediment loss through dam
Inadequate layer of aggregate on inside face or aggregate too coarse to restrict flow through dam.

Maintenance

- Inspect after each rainfall event.
- Remove sediment accumulations.
- Check structure and abutments for erosion, piping, or rock displacement. Repair immediately.
- Remove check dam after the contributing drainage area has been permanently stabilized. Smooth site to blend with surrounding area and stabilize according to vegetation plan.

References

Massachusetts Department of Environmental Protection, Office of Watershed Management, Nonpoint Source Program, ***Massachusetts Nonpoint Source Management Manual***, Boston, Massachusetts, June, 1993.

U.S. Environmental Protection Agency, ***Storm Water Management For Construction Activities***, EPA-832-R-92-005, Washington, DC, September, 1992.

Washington State Department of Ecology, ***Stormwater Management Manual for the Puget Sound Basin***, Olympia, WA, February, 1992.

Construction Entrance

A temporary stone-stabilized pad located at points of vehicular ingress and egress on a construction site.

Purpose

To provide a stable entrance and exit from a construction site and keep mud and sediment off public roads.

Where Practice Applies

Whenever traffic will be leaving a construction site and moving directly onto a public road or other paved areas.

Advantages

- Mud on vehicle tires is significantly reduced which avoids hazards caused by depositing mud on the public roadway.
- Sediment, which is otherwise contained on the construction site, does not enter stormwater runoff elsewhere.

Disadvantages

Effective only if installed at every location where traffic leaves and enters the site.

Planning Considerations

Avoid locating at curves in public roads or on steep slopes.

Construction entrances provide an area where mud can be removed from vehicle tires before they enter a public road. If the action of the vehicle traveling over the gravel pad is not sufficient to remove the majority of the mud, then the tires must be washed before the vehicle enters a public road.

If washing is used, provisions must be made to intercept the wash water and trap the sediment before it is carried off-site. Construction entrances should be used in conjunction with the stabilization of construction roads to reduce the amount of mud picked up by vehicles.

This practice will only be effective if sediment control is used throughout the rest of the construction site.

Design Recommendations

- Remove all vegetation and other objectionable material from the foundation area. Grade and crown foundation for positive drainage.
- Stone for a stabilized construction entrance shall be 1 to 3-inch stone, reclaimed stone, or recycled concrete equivalent placed on a stable foundation as specified in the plan.
- Pad dimensions: The minimum length of the gravel pad should be 50 feet, except for a single residential lot where a 30 foot minimum length may be used. Longer entrances will provide better cleaning action. The pad should extend the full width of the construction access road or 10 feet whichever is greater. The aggregate should be placed at least six inches thick.
- A geotextile filter fabric shall be placed between the stone fill and the earth surface below the pad to reduce the migration of soil particles from the underlying soil into the stone and vice versa. Filter cloth is not required for a single family residence lot.
- If the slope toward the road exceeds 2%, construct a ridge, 6 to 8 inches high with 3:1 side slopes, across the foundation approximately 15 ft from the entrance to divert runoff away from the public road.
- All surface water that is flowing to or diverted toward the construction entrance should be piped beneath the entrance. If piping is impractical, a berm with 5:1 slopes that can be crossed by vehicles may be substituted for the pipe.
- Washing: If the site conditions are such that the majority of mud is not removed from the vehicle tires by the gravel pad, then the tires should be washed before the vehicle enters the road or street. The wash area should be a level area with 3-inch washed stone minimum, or a commercial rack.
- Wash water should be directed into a sediment trap, a vegetated filter strip, or other approved sediment trapping device. Sediment should be prevented from entering any watercourses.
- A filter fabric fence should be installed down-gradient from the construction entrance in order to contain any sediment-laden runoff from the entrance.

Common Trouble Points

Inadequate runoff control
Sediment washes onto public road.

Stone too small, pad too thin, or geotextile fabric absent
Results in muddy condition as stone is pressed into soil.

Pad too short for heavy construction traffic
Extend pad beyond the minimum 50-ft length as necessary.

Pad not flared sufficiently at road entrance
Results in mud being tracked onto road and possible damage to road edge.

Unstable foundation
Use geotextile fabric under pad and/or improve foundation drainage.

Maintenance

- The entrance should be maintained in a condition that will prevent tracking or flowing of sediment onto public rights-of-way. This may require periodic topdressing with additional stone.
- Inspect entrance/exit pad and sediment disposal area weekly and after heavy rains or heavy use.
- Remove mud and sediment tracked or washed onto public road immediately.
- Mud and soil particles will eventually clog the voids in the gravel and the effectiveness of the gravel pad will not be satisfactory. When this occurs, the pad should be topdressed with new stone. Complete replacement of the pad may be necessary when the pad becomes completely clogged.
- If washing facilities are used, the sediment traps should be cleaned out as often as necessary to assure that adequate trapping efficiency and storage volume is available. Vegetative filter strips should be maintained to insure a vigorous stand of vegetation at all times.
- Reshape pad as needed for drainage and runoff control.
- Repair any broken road pavement immediately.
- All temporary erosion and sediment control measures shall be removed within 30 days after final site stabilization is achieved or after the temporary practices are no longer needed. Trapped sediment shall be removed or stabilized on site. Disturbed soil areas resulting from removal shall be permanently stabilized.

References

Minnick, E. L., and H. T. Marshall, ***Stormwater Management and Erosion Control for Urban and Developing Areas in New Hampshire***, Rockingham County Conservation District, August 1992.

North Carolina Department of Environment, Health, and Natural Resources, ***Erosion and Sediment Control Field Manual***, Raleigh, NC, February 1991.

U.S. Environmental Protection Agency, ***Storm Water Management For Construction Activities*** EPA-832-R-92-005, Washington, DC, September, 1992.

Washington State Department of Ecology, ***Stormwater Management Manual for the Puget Sound Basin***, Olympia, WA, February, 1992.

Construction Road Stabilization

Stabilization of temporary construction access routes, on-site vehicle transportation routes, and construction parking areas to control erosion

Where Practice Applies

All traffic routes and parking areas for temporary use by construction traffic.

Advantages

- Proper grading and stabilization of construction roads and parking areas reduces erosion and prevents dust problems.
- Road stabilization can significantly speed on-site work, avoid instances of immobilized machinery and delivery vehicles, and generally improve site efficiency and working conditions during adverse weather.

Disadvantages/Problems

- Measures on temporary roads must be cheap not only to install but also to demolish if they interfere with the eventual surface treatment of the area.
- May require maintenance to replace aggregate or repair ruts.

Planning Considerations

- Avoid steep slopes, excessively wet areas, and highly erodible soils.
- Controlling surface runoff from the road surface and adjoining area is a key erosion control consideration. Provide surface drainage and divert excess runoff to stable areas.

- Areas which are graded for construction vehicle transport and parking purposes are especially susceptible to erosion. The exposed soil surface is continually disturbed, leaving no opportunity for vegetative stabilization. Such areas also tend to collect and transport runoff waters along their surfaces. During wet weather, they often become muddy quagmires which generate significant quantities of sediment that may pollute nearby streams or be transported off-site on the wheels of construction vehicles. Dirt roads can become so unstable during wet weather that they are virtually unusable.
- Immediate stabilization of such areas with stone may cost money at the outset, but it may actually save money in the long run by increasing the usefulness of the road during wet weather.
- Permanent roads and parking areas should be paved as soon as possible after grading. As an alternative, the early application of stone may solve potential erosion and stability problems and eliminate later regrading costs. Some of the stone will also probably remain in place for use as part of the final base course of the road.

Design Recommendations

- A 6-inch course of 2 to 4-inch crushed rock, gavel base, or crushed surfacing base course should be applied immediately after grading or the completion of utility installation within the right-of-way. A 4-inch course of asphalt-treated base may be used in lieu of the crushed rock, or as advised by the local government.
- Temporary roads should follow the contour of the natural terrain to the maximum extent possible. Slope should not exceed 15 percent. Roadways should be carefully graded to drain transversely. Provide drainage swales on each side of the roadway in the case of a crowned section, or one side in the case of a super-elevated section.
- Drain inlets should be protected to prevent sediment-laden water entering.
- Areas adjacent to culvert crossings and steep slopes should be seeded and mulched.
- Dust control should be used when necessary.

Maintenance

- Inspect stabilized areas regularly, especially after large storm events. Add crushed rock if necessary and restabilize any areas found to be eroding.
- All temporary erosion and sediment control measures should be removed within 30 days after final site stabilization is achieved or after the temporary practices are no longer needed.
- Trapped sediment should be removed or stabilized on site. Disturbed soil areas resulting from removal should be permanently stabilized.

References

Massachusetts Department of Environmental Protection, Office of Watershed Management, Nonpoint Source Program, Massachusetts ***Nonpoint Source Management Manual,*** Boston, Massachusetts, June, 1993.

U.S. Environmental Protection Agency, ***Storm Water Management For Construction Activities*** EPA-832-R-92-005, Washington, DC, September, 1992.

Washington State Department of Ecology, ***Stormwater Management Manual for the Puget Sound Basin,*** Olympia, WA, February, 1992.

Diversion, Permanent

A permanent ridge or channel, or a combination ridge and channel, constructed: across sloping land; or at the top or bottom of a steep slope. Used to convey runoff water.

This practice is used to reduce slope lengths, break up concentration of runoff, and move water to stable outlets at a non-erosive velocity.

Where Practice Applies

This practice applies to sites where runoff can be diverted and used or disposed of safely to prevent flood damage or erosion and sediment damage, including:

- Above steep slopes to limit surface runoff onto the slope,
- Across long slopes to reduce slope length to prevent gully erosion,
- Below steep grades where flooding, seepage problems, or sediment deposition may occur,
- Around buildings or areas that are subject to damage from runoff.

Diversions must have stable outlets. The site, slopes, and soils must be such that the diversion can be maintained throughout its planned life.

Permanent diversions are not applicable below high sediment-producing areas unless land treatment practices, or structural measures, designed to prevent damaging accumulations of sediment in the channels, are installed with or before the diversions.

Advantages

Diversions are among the most effective and least costly practices for controlling erosion and sedimentation.

Planning Considerations

Permanent diversions should be planned as a part of initial site development. They are principally runoff control measures that subdivide the site into specific drainage areas.

Permanent diversions can be installed as temporary diversions until the site is stabilized then completed as a permanent measure, or they can be installed in final form during the initial construction operation. The amount of sediment anticipated and the maintenance required as a result of construction operations will determine which approach should be used.

Stabilize permanent diversions with vegetation or materials such as riprap, paving stone, or concrete as soon as possible after installation. Base the location, type of stabilization, and diversion configuration on final site conditions. Evaluate function, need, velocity control, outlet stability, and site aesthetics. When properly located, land forms such as landscape islands, swales or ridges can be used effectively as permanent diversions.

Base the capacity of a diversion on the runoff characteristics of the site and the potential damage after development. Consider designing an emergency overflow section or bypass area to limit damage from storms that exceed the design storm. The overflow section may be designed as a weir with riprap protection.

Design Recommendations

Capacity

Peak runoff values should be determined by accepted methods. Recommended minimum design frequencies are shown below. In all cases, the design storm frequency should be chosen to provide protection compatible with the hazard or damage that would occur if the diversion should overtop.

Homes, schools, industrial buildings, etc.	50-year design frequency
Playfields, recreation areas, similar land areas	25-year design frequency

Permissible Flow Velocity

Soil Texture	Bare Channel	Vegetated Channel
Sand, silty sandy loam	1.5 feet/second	2.5 feet/second
Silty clay and sandy clay loam	2.0 feet/second	3.5 feet/second
Clay	2.5 feet/second	4.5 feet/second

Cross Section

The channel may be parabolic or trapezoidal. It should be designed to have stable side slopes.

Side slopes for permanent diversions should not be steeper than 3:1 for maintenance purposes and preferably 4:1. In no case should side slopes be steeper than 1:1.

Back slope of the ridge is not to be steeper than 2:1 and preferably 4:1.

The ***ridge*** should include a settlement factor equal to 5 percent of its height.

The minimum ***top width*** of the diversion ridge after settlement is to be 4.0 feet at the design elevation.

Freeboard equalling 0.5 foot minimum.

In determining the cross section on temporary diversions, consideration should be given to soil type and frequency and type of equipment that is anticipated to be crossing the diversion.

Grade

Channel grade for diversions may be uniform or variable. The permissible velocity for the soil type and vegetative cover will determine maximum grade. Level diversions with blocked ends may be used, provided pipes of sufficient size and spacing are placed in the embankment to drain the channel after runoff stops.

Outlets

Diversions are to have adequate outlets which will convey runoff without damaging erosion. The following types of outlets are acceptable:

Natural or constructed vegetated outlets capable of safely carrying the design discharge. The outlet should be established and well vegetated prior to construction of the diversion.

Properly designed and constructed ***grade stabilization structures*** or ***storm sewers***.

Natural or constructed open channels which are stable and have adequate capacity and depth.

A ***stable area*** having a good sod cover or a woodland area with a deep erosion resistant litter. The outlet end of the diversion channel should be flared in a manner to spread the water over a wide area at a shallow depth.

Level Spreader

A level lip spreader should be used at diversion outlets discharging onto area already stabilized by vegetation. Spreaders shall be excavated at least 6 inches deep into undisturbed soil. The bottom of the excavation and the downstream lip of edge shall be level. Minimum spreader lengths shall be based on the peak rate of flow from a 10-year frequency storm.

Diversion Dikes

Diversion dikes should be used to divert runoff for temporary or permanent protection of cut or fill slopes. Diverted runoff must be discharged onto a stabilized area or through a slope-protection structure.

Recommended criteria:

- ***Drainage area*** - 5 acres or less.
- ***Top width*** - 2 feet minimum.
- ***Height*** (compacted fill) - 18 inches unless otherwise noted on the plans. (Height measured from the upslope toe to top of the dike.)
- ***Side slopes*** - 2:1 or flatter.
- ***Grade*** - dependent upon topography, but must have positive drainage to the outlet; may require vegetative or mechanical stabilization where grades are excessive.

Protection Against Sediment

Temporary diversions - None required.

Permanent diversions - As a minimum, a filter strip of close growing grass should be maintained above the channel. The width of the filter, measured from the center of the channel, should be one-half the channel width plus 15 feet.

The diversion ridge and channel should be vegetated to prevent erosion.

Small eroded areas and sediment-producing channels draining into the diversion should be shaped and seeded prior to or at the time the diversion is constructed.

Construction Recommendations

All trees, brush, stumps, and other objectionable material should be removed so they will not interfere with construction or proper functioning of the diversion.

All ditches or gullies which must be crossed should be filled and compacted prior to or as part of the construction.

Fence rows and other obstructions that will interfere with construction or the successful operation of the diversion should be removed.

The base for the diversion ridge should be prepared so that a good bond is obtained between the original ground and the placed fill. Vegetation should be removed and the base thoroughly disked before placement of the fill.

Vegetation

Diversions should be vegetated as soon after construction as practical. Give consideration to jute matting, excelsior matting, or sodding of channel to provide erosion protection.

Seeding, fertilizing, mulching, and sodding should be in accord with applicable vegetative standards for permanent cover. See Permanent Seeding.

One-half to one bushel of oats should be added to the basic mixture for quick cover and to help anchor the mulch.

Very moist channels are often best vegetated by working rootstocks of reed canarygrass into the seedbed.

When soil conditions are unfavorable for vegetation (such as very coarse-textured subsoil material), topsoil should be spread to a depth of 4 inches or more on at least the center half of parabolic shaped channels or on the entire bottom of trapezoidal shaped channels.

Seeded channels should be mulched. For critical sections of large channels, and for steep channels, the mulch should be anchored by cutting it lightly into the soil surface, or by covering with paper twine fabric or equivalent material; or jute netting should be used.

Maintenance

If no sediment protection is provided on temporary diversions, periodic cleanout will probably be required.

References

Massachusetts Department of Environmental Protection, Office of Watershed Management, Nonpoint Source Program, Massachusetts ***Nonpoint Source Management Manual,*** Boston, Massachusetts, June, 1993.

North Carolina Department of Environment, Health, and Natural Resources, ***Erosion and Sediment Control Field Manual***, Raleigh, NC, February 1991.

North Carolina Sediment Control Commission, ***Erosion and Sediment Control Planning and Design Manual***, Raleigh, NC, September, 1988.

Diversion, Temporary

A permanent ridge or channel, or a combination ridge and channel, constructed: across sloping land; or at the top or bottom of a steep slope. Used to convey runoff water.

Purpose

- To reduce slope lengths, break up concentration of runoff, and move water to stable outlets at a non-erosive velocity.
- To protect work areas from upslope runoff.
- To divert sediment-laden water to an appropriate sediment-trapping facility.

Where Practice Applies

This practice applies to construction areas where runoff can be diverted and disposed of properly to control erosion, sedimentation, or flood damage. Specific locations and conditions include:

- Above disturbed existing slopes, and above cut or fill slopes to prevent runoff over the slope;
- Across unprotected slopes, as slope breaks, to reduce slope length;
- Below slopes to divert excess runoff to stabilized outlets;
- Where needed to divert sediment-laden water to sediment traps;
- At or near the perimeter of the construction area to keep sediment from leaving the site;
- Above disturbed areas before stabilization to prevent erosion and maintain acceptable working conditions.
- Where active construction activities make the use of a permanent diversion unfeasible.

Temporary diversions may also serve as sediment traps when the site has been overexcavated on a flat grade. They may also be used in conjunction with a sediment fence.

Advantages

Diversions are among the most effective and least costly practices for controlling erosion and sedimentation.

Planning Considerations

A temporary diversion is intended to divert overland sheet flow to a stabilized outlet or a sediment trapping facility during establishment of permanent stabilization on a sloping disturbed area. When used at the top of a slope, the structure protects exposed slopes by keeping upland runoff away. When used at the base of a slope, the structure protects adjacent and downstream areas by diverting sediment-laden runoff to a sediment trapping facility.

If the diversion is going to remain in place for longer than 15 days, it should be stabilized with temporary or permanent vegetation.

It is important that diversions are properly designed, constructed and maintained since they concentrate water flow and increase erosion potential. Particular care must be taken in planning diversion grades. Too much slope can result in erosion in the diversion channel or at the outlet. A change of slope from steeper grade to flatter may cause deposition to occur. The deposition reduces carrying capacity and may cause overtopping and failure.

Frequent inspection and timely maintenance are essential to proper functioning.

Sufficient area must be available to construct and properly maintain diversions. It is usually less costly to excavate a channel and form a ridge or dike on the downhill side with the spoil than to build diversions by other methods. Where space is limited, it may be necessary to build the ridge by hauling in dike fill material or using a sediment fence to divert the flow. Use gravel to form the diversion dike where vehicles must cross frequently.

Temporary diversions may be planned to function one year or more, or they may be constructed anew at the end of each days grading operation to protect new fill.

Temporary diversions may serve as in-place sediment traps if overexcavated 1 to 2 feet and placed on a nearly flat grade. The dike serves to divert water as the stage increases. A combination silt fence and channel in which fill from the channel is used to stabilize the fence can trap sediment and divert runoff simultaneously.

Wherever feasible, build and stabilize diversions and outlets before initiating other landdisturbing activities.

Design Criteria

Temporary diversions must be planned to be stable throughout their useful life and meet criteria given below. Otherwise, they should be designed as permanent diversions.

Drainage area

Not more than three acres.

Capacity

Peak runoff from 10-year storm.

Minimum cross section:

Top Width	Height	Side Slopes
0 ft.	1.5 ft.	4:1
4 ft	1.5 ft.	2:1

Grade

The grade may be variable depending upon the topography and must have a positive grade to the outlet. The maximum channel grade should be limited to 1.0 percent.

Spacing
The maximum spacing of diversions on side slopes or graded rights-of-way should be no greater than the following:

Land Slope (%)	Spacing (ft.)
1 or less	300
2	200
3-5	150
5 or greater	100

Diverted runoff should outlet onto a stabilized area, into a properly designed waterway, grade stabilization structure or sediment trapping facility.

Diversions that are to serve longer than 30 working days should be seeded and mulched as soon as they are constructed, in order to preserve dike height and reduce maintenance.

Maintenance

Inspect temporary diversions once a week and after every rainfall.

Damage caused by construction traffic or other activity should be repaired before the end of each working day.

Immediately remove sediment from the flow area and repair the diversion ridge.

Check outlets carefully and make timely repairs as needed.

When the area protected has been permanently stabilized, remove the ridge and the channel to blend with the natural ground level, and appropriately stabilize it.

References

Massachusetts Department of Environmental Protection, Office of Watershed Management, Nonpoint Source Program, ***Massachusetts Nonpoint Source Management Manual***, Boston, Massachusetts, June, 1993.

North Carolina Department of Environment, Health, and Natural Resources, ***Erosion and Sediment Control Field Manual***, Raleigh, NC, February 1991.

North Carolina Sediment Control Commission, ***Erosion and Sediment Control Planning and Design Manual***, Raleigh, NC, September, 1988.

Washington State Department of Ecology, ***Stormwater Management Manual for the Puget Sound Basin***, Olympia, WA, February, 1992.

Dust Control

Reducing surface and air movement of dust from exposed soil surfaces during land disturbing, demolition, and construction activities.

Where Practice Applies

On construction routes and other disturbed areas subject to surface dust movement and dust blowing where on-site and off-site damage is likely to occur if preventive measures are not taken.

Advantages

A decrease in the amount of dust in the air will decrease the potential for accidents and respiratory problems.

Disadvantages/Problems

Excessive use of water to control dust emissions, particularly in areas where the soil has been compacted, can cause a runoff problem.

Planning Considerations

Large quantities of dust can be generated during land grading activities for commercial, industrial, or subdivision development, especially during dry, windy weather. Research at construction sites has established an average dust emission rate of 1.2 tons/acre/month for active construction. Earthmoving activities comprise the major source of construction dust emissions, but traffic and general disturbance of the soil also generate significant dust emissions.

In planning for dust control, it is important to schedule construction activities so that the least area of disturbed soil is exposed at one time.

For disturbed areas not subject to traffic, vegetation provides the most practical and efficient means of dust control. For other areas control measures include mulching, sprinkling, spraying adhesive or calcium chloride, and wind barriers.

Maintain dust control measures properly through dry weather periods until all disturbed areas have been permanently stabilized.

Methods

Vegetative Cover - For disturbed areas not subject to traffic, vegetation provides the most practical method of dust control.

Mulch (including Gravel Mulch) - When properly applied, mulch offers a fast, effective means of controlling dust.

Spray-on Adhesive - Latex emulsions or resin in water can be sprayed onto mineral soil to prevent particles from blowing away.

Calcium Chloride - Calcium chloride may be applied by mechanical spreader as loose, dry granules or flakes at a rate that keeps the surface moist but not so high as to cause water pollution or plant damage.

Sprinkling - The site may be sprinkled until the surface is wet. Sprinkling is especially effective for dust control on haul roads and other traffic routes.

Stone - Used to stabilize construction roads; can also be effective for dust control.

Barriers - A board fence, wind fence, sediment fence, or similar barrier can control air currents and blowing soil. All of these fences are normally constructed of wood and they prevent erosion by obstructing the wind near the ground and preventing the soil from blowing offsite.

A wind barrier generally protects soil downward for a distance of 10 times the height of the barrier. Perennial grass and stands of existing trees may also serve as wind barriers.

Maintenance

Respray area as necessary to keep dust to a minimum.

References

Massachusetts Department of Environmental Protection, Office of Watershed Management, Nonpoint Source Program, Massachusetts ***Nonpoint Source Management Manual,*** Boston, Massachusetts, June, 1993.

U.S. Environmental Protection Agency, ***Storm Water Management For Construction Activities***, EPA-832-R- 92-005, Washington, DC, September, 1992.

Washington State Department of Ecology, ***Stormwater Management Manual for the Puget Sound Basin***, Olympia, WA, February, 1992.

Filter Berm

A filter berm is a temporary ridge constructed of loose gravel, stone, or crushed rock. It slows and filters flow, diverting it from an exposed traffic area. It is used to retain sediment from traffic areas.

Where Practice Applies

Where a temporary measure is needed to retain sediment from rights-of-way or in traffic areas on construction sites.

Advantages

This is an efficient method of sediment removal.
Reduces the speed of runoff flow.

Disadvantages/Problems

- A gravel filter berm is more expensive to install than other practices which use materials found on-site.
- Has a limited life span.
- Can be difficult to maintain because of clogging from mud and soil on vehicle tires.

Design Criteria

Berm material should be ¾ to 3 inches in size, washed, well-graded gravel or crushed rock with less than 5 percent fines.

Spacing of berms:

- Every 300 feet on slopes less than 5 percent.
- Every 200 feet on slopes between 5 and 10 percent.
- Every 100 feet on slopes greater than 10 percent.

Berm dimensions:

- 1 foot high with 3:1 side slopes.
- 8 linear feet per 1 cfs runoff based on the 10-year, 24-hour design storm.

Maintenance

Filter berms should be inspected regularly after each rainfall, or if damaged by construction traffic. All needed repairs should be performed immediately.

Accumulated sediment should be removed and properly disposed of and the filter material replaced, as necessary.

References

U.S. Environmental Protection Agency, ***Storm Water Management For Construction Activities***, EPA-832-R-92-005, Washington, DC, September, 1992.

Washington State Department of Ecology, ***Stormwater Management Manual for the Puget Sound Basin***, Olympia, WA, February, 1992.

Filter Strip, Vegetated

A vegetated filter strip is an area of vegetation for runoff to flow through before it leaves a disturbed site or enters into a designed drainage system. It improves water quality by removing sediment and other pollutants from runoff as it flows through the filter strip. Some of the sediment and pollutants are removed by filtering, absorption, adsorption and settling as the velocity of flow is reduced.

Where Practice Applies

This practice applies to any site where adequate vegetation can be established and maintained. Vegetative filter strips can be used effectively:

- Surrounding stormwater management infiltration practices to reduce the sediment load delivered to the structures;
- Adjacent to water courses such as waterways and diversions and water bodies such as streams, ponds, and lakes;
- At the outlets of stormwater management structures; or
- Along the top of and at the base of slopes.

A vegetative filter strip is designed to provide runoff treatment of conventional pollutants but not nutrients. This practice is not designed to provide streambank erosion control. A vegetative filter strip should not be used for conveyance of larger storms because of the need to maintain sheet flow conditions. Also, the filter strip would likely be prohibitively large for this application.

Planning Considerations

Filter strips may occur naturally or be constructed. It is important that filter strips be designed and constructed so that runoff flows uniformly across the filter strip as sheet flow. Once the flow becomes concentrated in rills, the effectiveness of the strip is greatly reduced. It is essential that some type of device such as a level spreader or shallow stone trench be used to distribute the runoff evenly across the strip.

Natural filter areas can provide excellent pollutant removal, particularly those areas left adjacent to natural water courses and bodies of water. It is also important to evenly distribute the runoff into these natural areas for best performance. These natural areas can provide excellent wildlife habitat and travel corridors.

To prevent soil compaction, no equipment should be allowed to operate within the filter strip area. Uncompacted soil encourages percolation and minimizes rapid surface runoff.

Design Recommendations

Drainage Area
Maximum recommended drainage area is 5 acres.

Entrance Conditions
Runoff must be introduced to the filter strip as uniform sheet flow. A level spreader can be used to distribute the runoff onto the filter strip by constructing the lip of the spreader and the top of the strip at the same elevation or contour. In some cases, a shallow stone trench can be used to intercept the runoff and allow the water to outlet evenly as long as the lower edge of the stone trench is constructed level. Make provisions to avoid flow bypassing the filter strip.

Length
Filter strip length (parallel to flow) should be designed to produce a water residence time of at least 20 minutes (the length should normally be in the range of 100-200 feet).
Vegetative filter strips should not receive concentrated flow discharges as their effectiveness will be destroyed plus the potential for erosion could cause filter strips to become sources of pollution.

Slope
Vegetative filter strips should not be used on slopes greater than about 15 percent because of the difficulty in maintaining the necessary sheet flow conditions.

Width of Strip
The minimum width of a filter strip should be 20 feet for slopes up to 1%. An additional 4 feet for each 1% of slope should be added. Experience has found that strips from 50 to 75 feet wide perform best.

Vegetation
A dense stand of vegetation is necessary for a well functioning filter strip. A temporary diversion should be used to divert runoff away from the filter strip until good vegetation is established; otherwise rills will develop and reduce the effectiveness of the strip.

Maintenance

Filter strips should be maintained as natural areas once the vegetation is established. The filter strip should be protected from damage by fire, grazing, traffic, and dense weed growth.

Fertilization needs should be determined by on-site inspections. Supplemental fertilizer is a key factor, as most species take two to three years to become fully established.

The filter strip should be inspected periodically and after every major rainstorm to determine if the entrance conditions are still uniform and level and to see if rills have formed. Any problem areas should be repaired promptly to prevent further deterioration.

References

Minnick, E. L., and H. T. Marshall, ***Stormwater Management and Erosion Control for Urban and Developing Areas in New Hampshire,*** Rockingham County Conservation District, August 1992.

Massachusetts Department of Environmental Protection, Office of Watershed Management, Nonpoint Source Program, ***Massachusetts Nonpoint Source Management Manual,*** Boston, Massachusetts, June, 1993.

Washington State Department of Ecology, ***Stormwater Management Manual for the Puget Sound Basin***, Olympia, WA, February, 1992.

Flume, Paved

A paved flume is a permanent lined channel constructed on a slope. Paved flumes are used routinely on parking lot fills and highway cuts and fills to take runoff down the slope without causing erosion. The flumes may be constructed of concrete, asphalt, or masonry. The outlet of the flume should be protected to avoid erosion.

Where Practice Applies

This is a permanent practice that applies where stormwater runoff must be conveyed from the top of a cut or fill slope to the bottom.

Design Recommendations

This practice should be designed by a professional engineer.

Capacity

Paved flumes should be designed to pass the peak rate of flow expected from a 10 year frequency storm unless local regulations require a lower frequency higher discharge storm event.

Slope
The steepest slope of the structure shall be 1.5 horizontal to 1 vertical (1.5: 1) where the flume is located in natural ground. The maximum slope shall be 2 horizontal to 1 vertical (2:1) on fill slopes.

Cutoff Walls
Cutoff walls shall be provided at the beginning and end of the flume. The wall should extend the full width of the flume and a minimum of 18 inches into the soil below the bottom of the flume. Cutoff wall should be at least 6 inches thick. Concrete walls should be reinforced with #4 bars spaced on 6 inch centers in both directions.

Cross section
Concrete flume walls will need to be at least 4 inches thick and reinforced with welded wire fabric.
Asphalt lined flumes should be at least 3 inches thick.
Masonry flumes should be a minimum of 4 inches thick.

Bedding
All paved flumes should be constructed on a 6 inch layer of sand-gravel bedding material.

Outlet
Outlets of paved flumes must be protected from erosion with some type of energy dissipater. The dissipater may be a designed structure or may be constructed of rock riprap capable of withstanding the velocity of flow from the chute.

Maintenance

Little maintenance is required for a paved flume, but the flume should be inspected periodically to see if cracks have developed in the lining. Any cracks should be repaired immediately. The energy dissipater should be checked to see that it is functioning properly. Any erosion below the dissipater should be repaired immediately.

References

Minnick, E. L., and H. T. Marshall, ***Stormwater Management and Erosion Control for Urban and Developing Areas in New Hampshire,*** Rockingham County Conservation District, August 1992.

Massachusetts Department of Environmental Protection, Office of Watershed Management, Nonpoint Source Program, ***Massachusetts Nonpoint Source Management Manual, Boston***, Massachusetts, June, 1993.

Gabions

Gabions are rectangular baskets fabricated from a hexagonal mesh of heavily galvanized steel wire. The baskets are filled with stone and rock and stacked atop one another to form a gravity-type wall. Gabions depend mainly on the interlocking of the individual stones and rocks within the wire mesh for internal stability, and their mass or weight to resist hydraulic and earth forces. Gabions are a porous type of structure that can be vegetated.

Purpose

To slow the velocity of concentrated runoff or to stabilize slopes with seepage problems and/or noncohesive soils.

Where Practice Applies

Soil-water interfaces, where the soil conditions, water turbulence, water velocity, and expected vegetative cover, are such that the soil may erode under the design flow conditions. Gabions can be used on steeper slopes than riprap.

Advantages

Some advantages of gabion walls are:

- Ease of handling and transportation
- Speed of construction
- Flexibility (Gabions tolerate movement)
- Permeability to water (Good drainage)

Gabions offers an easy-to-use method for decreasing water velocity and protecting slopes from erosion.

Disadvantages/Problems

Gabions are sometimes criticized as being unsightly. They can be made more attractive by use of attractive facing stone toward the front of the wall and by establishing vegetation in the spaces between the rocks.

Gabions are more expensive than either vegetated slopes or riprap.

The wire baskets used for gabions may be subject to heavy wear-and-tear due to wire abrasion by bedload movement in streams with high velocity flow.

Planning Considerations

For easy handling and shipping, gabions are supplied folded into a flat position and bundled together. Gabions are readily assembled by unfolding and binding together all vertical edges with lengths of connecting wire stitched around the vertical edges. The empty gabions are placed in position and wired to adjoining gabions. They are then filled with cobblestone-size rock (10-30 cm in diameter) to one-third their depth. Connecting wires, placed in each direction, brace opposing gabion walls together. The wires prevent the gabion baskets from "bulging" as they are filled. This operation is repeated until the gabion is filled. After filling, the top is folded shut and wired to the ends, sides, and diaphragms.

During the filling operation live rooting plant species, such as willow, may be placed among the rocks. If this is done, some soil should be placed in the gabions with the branches, and the basal ends of the plants should extend well into the backfill area behind the gabion breast wall.

Several different design configurations are possible with gabions. They may have either a battered (sloping) or a stepped-back front. The choice depends upon application, although the stepped-back type is generally easier to build when the wall is more than 10 ft high.

If large rocks are readily accessible, inexpensive, and near the proposed site, then their use in construction of a rock wall may be preferable. On the other hand, if rock must be imported or is only available in small sizes, a gabion wall may be preferable.

Sequence of Construction

Since gabions are used where erosion potential is high, construction must be sequenced so that they are put in place with the minimum possible delay. Disturbance of areas where gabions are to be placed should be undertaken only when final preparation and placement can follow immediately behind the initial disturbance.

Where gabions are used for outlet protection, they should be placed before or in conjunction with the construction of the pipe or channel so that they are in place when the pipe or channel begins to operate.

Maintenance

Gabions should be inspected on a regular basis and after every large storm event.

All temporary and permanent erosion and sediment control practices shall be maintained and repaired as needed to assure continued performance of their intended function. All maintenance and repair shall be conducted in accordance with an approved manual.

References

Connecticut Council on Soil and Water Conservation, ***Connecticut Guidelines for Soil Erosion and Sediment Control***, Hartford, CT, January, 1985.

Gray, Donald H. and Leiser, A. T., ***Biotechnical Slope Protection and Erosion Control***, Leiser Van Reinhold Inc., 1982.

Pennsylvania, Commonwealth of, Bureau of Soil and Water Conservation, ***Erosion and Sediment Pollution Control Program Manual***, Harrisburg, PA, April, 1990.

Geotextiles

Geotextiles are porous fabrics known in the construction industry as filter fabrics, road rugs, synthetic fabrics, construction fabrics, or simply fabrics. Geotextiles are manufactured by weaving or bonding fibers made from synthetic materials such as polypropelene, polyester, polyethylene, nylon, polyvinyl chloride, glass and various mixtures of these.

Some geotextiles are also biodegradable materials such as mulch matting and netting. Mulch mattings are materials (jute or other wood fibers) that have been formed into sheets of mulch that are more stable than normal mulch. Netting is typically made from jute, other wood fiber, plastic, paper, or cotton and can be used to hold the mulching and matting to the ground.

Purpose

As a synthetic construction material, geotextiles are used for a variety of purposes in the United States and other countries. The uses of geotextiles include separators, reinforcement, filtration and drainage, and erosion control. Netting can also be used alone to stabilize soils while the plants are growing; however, it does not retain moisture or temperature well.

Where Practice Applies

Geotextiles, when used alone, can be used as matting. Mattings are used to stabilize the flow in channels and swales. Matting may also be used on recently planted slopes to protect seedlings until they become established and on tidal or stream banks where moving water is likely to wash out new plantings.

Geotextiles are also used as separators. An example of such a use is geotextile as a separator between riprap and soil. This ‘sandwiching’ prevents the soil from being eroded from beneath the riprap and maintaining the riprap’s base.

Advantages

- Fabrics are relatively inexpensive for certain applications.
- A wide variety of geotextiles to match specific needs is available.

Disadvantages/Problems

If the fabric is not property selected, designed, or installed, the effectiveness may be reduced drastically.

Many synthetic geotextiles are sensitive to light and must be protected prior to installation.

Planning Considerations

There are numerous types of geotextiles available, therefore the selected fabric should match its purpose. In the field, important concerns include regular inspections to check for cracks, tears, or breaches in the fabric.

Effective netting and matting require firm, continuous contact between the materials and the soil. If there is no contact, the material will not hold the soil and erosion will occur underneath the material.

References

“Installing Erosion Control Blankets,” ***Erosion Control, The Journal For Erosion & Sediment Control Professionals***, Vol. 1, No. 4, September/ October 1994.

U.S. Environmental Protection Agency, ***Storm Water Management For Construction Activities***, EPA-832-R- 92-005, Washington, DC, September, 1992.

Grade Stabilization Structure

A permanent structure used to drop water from a higher elevation to a lower elevation. Grade stabilization structures are used to reduce or prevent excessive erosion by reducing velocities in a watercourse or by providing channel linings or structures that can withstand high velocities.

Where Practice Applies

This practice applies to sites where earth and vegetation cannot safely handle water at permissible velocities, where excessive grades or overfall conditions are encountered, or where water is to be structurally lowered from one elevation to another. These structures should be planned and installed along with or as a part of other conservation practices in an overall surface water disposal system.

Planning Considerations

Permanent grade stabilization structures may be constructed of concrete, metal, rock riprap, timber, or other suitable material. The choice of material is dependent on the proposed life of the structure, availability of materials, site specification, and soil conditions where the structure will be installed.

Generally, concrete structures are more expensive and more complicated to build, however they are more durable. Prefabricated metal structures are available at a slightly lower cost and are not as complicated to install. Rock riprap is a less expensive alternative where an adequate supply of durable rock is available, but will require more maintenance. Timber structures are not as easily installed as rock riprap, nor are they as durable.

Permanent grade stabilization structures are dependent on adequate tailwater conditions for proper functioning. Without adequate tailwater, erosion at the toe of the structure will eventually cause failure.

Design Recommendations

Design and specifications should be prepared for each structure on an individual job basis by a qualified engineer.

Overfall structures of concrete, metal, rock riprap, or other suitable material may be used to lower water from one elevation to another. These structures are applicable where it is desirable to drop the watercourse elevation over a very short horizontal distance. Adequate protection should be provided to prevent erosion or scour problems at both the upstream and downstream ends of the structure as well as along sides of the structure.

Pipe drops of metal pipe may be used with suitable inlet and outlet structures. The inlet structure may consist of a vertical section of pipe, an embankment, or a combination of both. The outlet structure shall provide adequate protection against erosion or scour at the pipe outlet.

Capacity

Structures which are designed to operate in conjunction with other erosion control practices should have as a minimum sufficient capacity to handle the bankfull capacity of the channel delivering water to the structure.

The minimum design capacity for grade control structures that are not designed to perform in conjunction with other practices should be that required to handle a 25-year frequency 24-hour duration storm.

Runoff values should be computed using accepted methods.

Maintenance

Grade stabilization structures should be checked at least annually and after every major storm. Concrete structures should be checked for concrete deterioration, settlement, and joint integrity. Pipe structures should be checked for deterioration of the pipe, settlement, and joint integrity. The outlets of the structures should be checked to see if the outlet is stable and is not eroding. If repairs are necessary, they should be made immediately to avoid further damage to the structures.

References

Minnick, E. L., and H. T. Marshall, ***Stormwater Management and Erosion Control for Urban and Developing Areas in New Hampshire***, Rockingham County Conservation District, August 1992.

Inlet Protection

A sediment filter or an excavated impounding area around a storm drain, drop inlet, or curb inlet.

Used to prevent sediment from entering storm drainage systems prior to permanent stabilization of the disturbed area. This practice allows for early use of the drainage system.

Where Practice Applies

Where storm drains are to be made operational before permanent stabilization of the disturbed drainage area.

Inlet protection is a temporary measure used where the drainage area to the inlet or inlets of a storm drain system is disturbed and it is not possible to divert sediment laden water away from the system. Storm sewers which are put into use before their drainage area is stabilized can convey large amounts of sediment to natural drainageways. This practice should not be used to replace other sediment trapping devices, but it should be used in conjunction with these devices to help prevent sediment from being transported into the system and ultimately downstream or offsite.

Runoff from disturbed areas larger than one acre should be routed through a temporary sediment trap or basin.

Filter fabric is used for inlet protection when storm water flows are relatively small with low velocities.

Block and gravel filters can be used where velocities are higher.

Gravel and mesh filters can be used where flows are higher and subject to disturbance by site traffic.

Sod inlet filters may be used if sediment load in the storm water runoff is low.

Advantages

- Prevents clogging of storm drainage systems and siltation of receiving waters.
- Reduces the amount of sediment leaving the site.

Disadvantages/Problems

- May be difficult to remove collected sediment, especially under high flow conditions.
- May cause erosion elsewhere if clogging occurs.
- Practical only for low sediment, low volume flows.

Planning considerations

Installation of this measure should take place before any soil disturbance in the drainage area. Inlet protection should be used in combination with other measures, such as small impoundments or sediment traps, to provide more effective sediment removal.

The type of inlet protection device chosen depends on site conditions. Straw or hay bale barriers or sediment fences can be constructed around inlets. A small sediment basin can be excavated around the storm drain inlet. In other cases, gravel filters may be used around or directly over the storm sewer opening.

The major considerations in deciding the type of protection to be used must be based on the type of inlet, the conditions around the inlet, and the area adjacent to the inlet that may be damaged or inconvenienced because of temporary ponding of water.

Design Recommendations

- Grates and spaces of all inlets should be secured to prevent seepage of sediment-laden water.
- All inlet protection measures should include sediment sumps of 1 to 2 feet in depth, with 2:1 side slopes.
- The inlet protection device should be constructed so that any ponding resulting from the installation will not cause damage to adjacent areas or structures.

- The device must be constructed so that clean-out and disposal of trapped sediment and debris can be accomplished with little interference to construction activities.

Drainage Area

The drainage area normally should be no more than one acre.

Capacity

Runoff from 10-year storm must enter storm drain without bypass flow.

Types of Inlet Protection

Straw or Hay Bale Barriers

Straw or hay bale barriers can be constructed around the drain inlet.

Permeability through bales is lower than for other types of inlet protection, such as sediment fences. Provide sufficient storage space for runoff or sufficient lineal footage of bales to allow storm flow to pass through the bales.

Excavated Drop Inlet Trap

This method of inlet protection is applicable where relatively heavy flows are expected and overflow capability is needed.

Applicable where the inlet drains a relatively small (less than one acre) flat area, on less than 5 percent slope. This practice works well for trapping coarse grained material. Do not place fabric under gate as the collected sediment may fall into the drain when the fabric is retrieved. This practice cannot easily be used where the area is paved because of the need for driving stakes to hold the material.

Excavated traps may be used to improve the effectiveness and reliability of other sediment traps and barriers such as fabric, or block and gravel inlet protection.

Installation:

The trap should be excavated around the inlet to provide 67 cubic feet of storage per acre of drainage area to the inlet. The trap should be no less than 1 foot deep or more than 2 feet deep when measured from the top of the inlet. Side slopes should be 3:1 or flatter.

Dimensions of the excavation should be based on the site conditions. Normally the traps are square. If there is concentrated flow being directed into the trap, however, then the trap should be rectangular with the long dimension oriented in the direction of the flow.

When necessary, spoil may be placed to form a dike on the downslope side of the excavation to prevent bypass flow.

Common Trouble Points

Sediment fills excavated basin and enters storm drain
Sediment-producing area too large for basin design or inlet not properly maintained.
Excessive ponding
Gravel over weep holes may be plugged with sediment. Remove debris, clear sediment, and replace gravel.
Flooding and erosion due to blockage of storm drain
Install trash guard.

Gravel and Wire Mesh Filter

Applicable where flows greater than 0.5 cfs are expected and construction traffic may occur over the inlet.
Installation
A wire mesh should be placed over the drop inlet or curb opening so that the entire opening and a minimum of 12 inches around the opening are covered by the mesh. The mesh may be ordinary hardware cloth or wire mesh with openings up to ½ inch. If more than one strip of mesh is necessary, overlap the strips. Place filter fabric over wire mesh.

Extend the filter fence/wire mesh beyond the inlet opening at least 18 inches on all sides. Place ¾ to 3-inch gravel over the filter fabric/wire mesh. The depth of the gravel should be at least 12 inches over the entire inlet opening.

Block and Gravel Inlet Protection

This method uses standard concrete block and gravel to provide a small, sturdy barrier to trap sediment at the entrance to a storm drain. It applies to both drop inlets and curb inlets where heavy flows are expected and an overflow capacity is necessary to prevent excessive ponding around the structure.

Concrete blocks are laid without mortar closely around the perimeter of the drain. Gravel is then placed around the outside of the blocks to restrict the flow and form a sediment pool. For slower drainage and therefore more settlement time, the concrete blocks could be eliminated and the device made entirely of gravel.

Pool depth should be limited to a maximum of 2 feet.

Frequent maintenance is a must for this practice.
Installation:
Place wire mesh over the drop inlet so that the wire extends a minimum of 1 foot beyond each side of the inlet structure. Use hardware cloth or comparable wire mesh with one-half inch openings. If more than one strip is necessary, overlap the strips. Place filter fabric over the wire mesh.

Place concrete blocks lengthwise on their sides in a single row around the perimeter of the inlet, so that the open ends face outward, not upward. The ends of adjacent blocks should abut. The height of the barrier can be varied, depending on design needs, by stacking combinations of blocks that are 4 inches, 8 inches, and 12 inches wide. The row of blocks should be at least 12 inches but no greater than 24 inches high.

Place wire mesh over the outside vertical face (open end) of the concrete blocks. Extend at least 12 inches around the opening to prevent aggregate from being transported through the openings in the block. Use hardware cloth or comparable wire mesh with ½ inch openings.

Pile gravel, 1-inch diameter or smaller, against the wire mesh to the top of the outside face of the blocks to control drainage rate.

Common Trouble Points

Top of structure too high

- Bypass storm flow causes severe erosion.

Blocks not placed firmly against storm drain inlet

- Scour holes develop.

Drainage area too large

- Poor trap efficiency and/or sediment overload.

Approach to drain too steep

- Causes high flow velocity and poor trap efficiency. Install excavated basin in the approach.

Sediment not removed following a storm

- Sediment enters storm drain.

Stone in gravel donut not large enough or inside slope too steep

- Stone washes into inlet.

Maintenance

Remove and replace gravel over weep holes when drainage stops.

Fabric Drop Inlet Protection

A temporary device consisting of porous fabric supported by posts and placed around a drop inlet.

When properly braced and sealed at the bottom, the fabric restricts flow rate, forming a sedimentation pool at the approach to the inlet. The fabric allows the pool to drain slowly, protecting the storm drain from sediment.

This method of inlet protection is effective where the inlet drains a small, nearly level area with slopes generally less than 5 percent and where shallow sheet flows are expected.

The immediate land area around the inlet should be relatively flat (less than 1%) and located so that accumulated sediment can be easily removed.

This method cannot easily be used where the area is paved because of the need for driving stakes to hold the material.

Height of fabric
1.5 ft maximum, 1 foot minimum; measured from top of inlet.

Stability
Structure must withstand 1.5-foot head of water and sediment without collapsing or undercutting.

Support posts
Steel fence posts or 2 x 4-inch wood, length 3 foot minimum, spacing 3 foot maximum; top frame support recommended.

Fabric material
Synthetic, extra-strength fabric. Burlap is acceptable for short-term use only (60 days or less).

Installation:

Space support posts evenly against the perimeter of the inlet a maximum distance of 3 ft apart and drive them at least 8 inches into the ground. The stakes must be at least 3 feet long. Overflow must fall directly into the inlet and not on unprotected soil.

Build a supporting frame of 2 x 4-inch lumber, maximum height 1.5 ft above the drop inlet crest. The frame adds stability and serves as a weir to control storm overflow into the drop inlet. Alternatively, use wire fence (14 gauge minimum, with a maximum mesh spacing of 6 inches) to support fabric. Stretch fence with top level to provide uniform overflow. Extend wire 6 inches below ground.

Excavate a trench approximately 8 inches wide and 12 inches deep around the outside perimeter of the stakes.

Cut fabric from a single roll to eliminate joints. Place bottom 12 inches of fabric in trench adjacent to the drop inlet.

Fasten fabric securely to the posts and frame or support fence, if used. Overlap joints to the next post.

Backfill the trench with ¾ inch or less washed gravel all the way around.

Do not place fabric under grate as the collected sediment may fall into the drain when the fabric is retrieved.

Stabilize disturbed areas immediately after construction.

Common Trouble Points:

Posts and fabric not supported at the top

- Results in collapse of the structure.

Fabric not properly buried at bottom

- Results in undercutting.

Top of fabric barrier set too high

- Results in flow bypassing the storm inlet or collapsing structure.

Temporary dike below the drop inlet not maintained

- Results in flow bypassing storm inlet

Sediment not removed from pool

- Results in inadequate storage volume for next storm.

Fence not erected against drop inlet

- Results in erosion and undercutting.

Land slope at storm drain too steep

- Results in high flow velocity, poor trapping efficiency, and inadequate storage volume. Excavation of sediment storage area may be necessary.

Sod Drop Inlet Protection

A permanent grass sod filter area around a storm drain drop inlet in a stabilized, well vegetated area.

Where Practice Applies:

- Where the drainage area of the drop inlet has been permanently seeded and mulched and the immediate surrounding area is to remain in dense vegetation.
- This practice is well suited for lawns adjacent to large buildings.
- The drainage area should not exceed 2 acres,
- The entrance flow velocity must be low, and
- The general area around the inlet should be planned for vegetation.

Other Inlet Protection Practices

There are several types of manufactured inlet filters and traps which have different applications dependent upon site conditions and type of inlet. One is a catchbasin filter that prevents sediments and other contaminants from entering storm drainage systems. The catchbasin filter is inserted in the catchbasin just below the grating. The catchbasin filter is equipped with a sediment trap and up to three layers of a fiberglass filter material.

This is a changing field. New products are being developed and brought to the market. For the most recent information see a trade journal such as Erosion Control or Land and Water.

Maintenance

All trapping devices and the structures they protect should be inspected after every rain storm and repairs made as necessary.

Sediment should be removed from the trapping devices after the sediment has reached a maximum of one half the depth of the trap.

Sediment should be disposed of in a suitable area and protected from erosion by either structural or vegetative means.

Temporary traps should be removed and the area repaired as soon as the contributing drainage area to the inlet has been completely stabilized.

Systems using filter fabric

Inspections should be made on a regular basis, especially after large storm events. If the fabric becomes clogged, it should be replaced.

Systems using stone filters

If the stone filter becomes clogged with sediment, the stones must be pulled away from the inlet and cleaned or replaced. Since cleaning of gravel at a construction site may be difficult, an alternative approach would be to use the clogged stone as fill and put fresh stone around the inlet.

References

Massachusetts Department of Environmental Protection, Office of Watershed Management, Nonpoint Source Program, Massachusetts ***Nonpoint Source Management Manual***, Boston, Massachusetts, June, 1993.

Minnick, E. L., and H. T. Marshall, ***Stormwater Management and Erosion Control for Urban and Developing Areas in New Hampshire,*** Rockingham County Conservation District, August 1992.

North Carolina Department of Environment, Health, and Natural Resources, ***Erosion and Sediment Control Field Manual***, Raleigh, NC, February 1991.

U.S. Environmental Protection Agency, ***Storm Water Management For Construction Activities***, EPA-832-R-92-005, Washington, DC, September, 1992.

Washington State Department of Ecology, ***Stormwater Management Manual for the Puget Sound Basin***, Olympia, WA, February, 1992.

Land Grading and Stabilization

Using engineering techniques or vegetative practices, or a combination of both, to provide surface drainage and control erosion and sedimentation while reshaping and stabilizing the ground surface to provide more suitable sites for buildings and other facilities, or maintain temporary stockpiles.

Where Practice Applies

This practice applies where the existing ground surface is regraded, new cut or fill slopes are created, or existing slopes or ground surfaces would otherwise be unstable or subject to erosion.

Planning Considerations

Provisions should be made to safely conduct surface runoff to storm drains, protected outlets, or to a stable watercourse to insure that the runoff will not damage slopes or other graded areas.

Wherever possible runoff water should be diverted away from the top of cut and fill slopes to stable outlets or grade control structures.

Waterways, diversions, grade stabilization structures, terraces, pipe drains, flumes, subsurface drains, or rock fills are some of the practices that may find use in slope stabilization. Bioengineering practices, combining vegetative and mechanical practices, also have a place.

Cuts, Fills, and Slopes

Compaction can be a major factor in erosion control for fill slopes. In addition to other compaction controls required by the nature of the project, the minimum criterion recommended for successful erosion control on fill slopes is to compact the uppermost one foot of fill to at least 85 percent of the maximum unit weight (based on the modified AASHTO compaction test). This is usually accomplished by running heavy equipment over the fill.

On cut slopes ground water seepage causes undercutting and soil slippage. Subsurface drains, a layer of crushed rock, or other measures may be necessary.

Slope gradient is an important factor in the success of vegetative restabilization measures. Normal tillage equipment cannot be used to prepare a seedbed on slopes 2:1 or steeper. Storm water runoff will result in the loss of seeds, fertilizer, and soil.

Sod can be used to stabilize steep slopes instead of seeding where grades are not more than 2:1. Sod on slopes steeper than 3:1 should be pegged.

Slopes steeper than 2:1 will usually require special stabilization measures such as a crushed rock or riprap layer, crib wall or revetment.

Sandy soils present a special problem for the establishment of vegetation, especially in areas where the sand is deep and droughty. American beachgrass is one solution to this problem. It is usually established by hand planting.

Steeply sloped areas such as lakeshores and road banks involve three special considerations:

- To insure reasonable success in stabilization, bank slopes should be 2:1 or flatter.
- The toe of the slope must be protected from undercutting by mechanical means where necessary.
- Water seeping from the face of the slope should be intercepted by a drainage system.

Borrow and Stockpile Areas

Borrow areas, especially those that are located off the development site, must be considered in erosion and sedimentation control planning. Borrow areas, as well as stockpile and spoil areas, must be stabilized.

Borrow and stockpile areas present the same set of problems for the control of erosion and sedimentation as exposed cut and fill slopes. Runoff should be diverted from the face of the slopes which are exposed in the excavation process. The runoff must then be conveyed in stabilized channels to stable disposal points.

The measures used to control erosion on slopes should also be used in borrow areas. Only those sections of the borrow area which are currently needed to supply fill should be stripped. Immediately after the required fill has been taken, the exposed area should be stabilized.

If final grading is delayed, temporary seeding should be used. By properly timing the disturbance of the natural cover in the borrow area in carefully planned phases, the area of exposed soil and the duration of exposure is reduced and, therefore, erosion losses are reduced.

Topsoil from borrow areas is usually stripped and stockpiled for later redistribution on the disturbed area. These stockpiles should be located on the uphill side of the excavated area wherever possible so that they can act as diversions. Stockpiles should be shaped and seeded with temporary cover.

Where borrow areas are off the development site, a separate system for trapping sediment from the area is needed.

After the excavation is complete, borrow areas should be regraded to insure proper drainage and to blend the borrow area with the surrounding topography. Stockpiled topsoil is then redistributed and permanent vegetative cover established.

Exposed Surfaces

Although erosion rates on steep exposed slopes are higher than on flat or gently sloping areas, all areas of exposed soil are vulnerable to erosion. If erosion control is ignored on larger areas of nearly flat or gently sloping land, it will be possible for significant amounts of soil to be eroded. Clearing, grading, and vegetative restabilization in these areas can be timed so that the extent of exposed area and the duration of exposure is minimized. These areas require prompt vegetative restabilization. Temporary seeding or mulching is required where larger areas will not be permanently stabilized within recommended time limits. Diversions, sediment barriers, or traps constructed on the lower side of large disturbed areas should be used to intercept and collect sediment.

Right-of-ways and parking areas that are being prepared for paving must be protected from rainfall and runoff. Diversions should be constructed to protect these areas from runoff before clearing and grading begin.

Areas that are being prepared for paving should be properly compacted because compaction makes the exposed surface area less vulnerable to erosion. Cleared right-of-ways may be covered with crushed aggregate to reduce erosion. If right-of-ways will not be used for construction traffic, they can be seeded with temporary cover.

Gravel or stone filter berms should be used at intervals along a right-of-way to intercept runoff and direct it to stabilized areas, drainageways, or enclosed drainage system inlets. Filter berms slow runoff, filter it, and collect sediment. The berms will need some continuing maintenance, but can be crossed by construction equipment.

Paved Surfaces

An increase in paved surface area on a site greatly boosts the rate of site runoff. For example, a 20 percent increase in paved area can double the rate of runoff during a heavy rainfall. In addition, the velocity of runoff moving across a paved surface is higher than the velocity of runoff moving across an area of exposed earth of vegetation. Pavement provides very little resistance to flow and does not allow any infiltration (except for porous pavement).

Construction Areas and Eroding Areas

Types of plantings

When erosion or sediment control is of primary and immediate concern, these areas are usually initially stabilized by seeding grass cover. When necessary, the site should be prepared by seeding temporary vegetative cover. Jute netting or anchored mulch should be used in conjunction with seeding at critical locations where water concentrates.

Seeding mixtures

When dense plant cover is needed for erosion and sediment control, or for appearances, seedings of enduring herbaceous species should be used. See the Permanent Seeding and Temporary Seeding practices. One-half to one bushel of oats, or 1 to 1 ½ bushels of rye should usually be added to the basic mixture for quick cover.

Mulching

Where plantings are on areas subject to mulch removal by wind or water flows, the mulch should be anchored. Mulched areas should be checked periodically and immediately after severe storms for damage until the desired purpose of the mulching is achieved. Any damaged areas should be repaired as soon as discovered.

Design Recommendations

Cut or fill slopes which are to be vegetated should not be steeper than 2 horizontal to 1 vertical. If a slope is to be mowed, it should be 3:1 or flatter. Slopes of materials not to be vegetated should be at the safe angle of repose for the materials encountered.

Provisions should be made to safely conduct surface water to storm drains or suitable natural water courses and to prevent surface runoff from damaging cut faces and fill slopes.

Terraces or diversions should be provided whenever the height of the cut or fill exceeds 20 feet. The “benches” should divide the slope face as equally as possible and should convey the water into stable outlets. Benches should be kept free of sediment during all phases of development.

Seeps or springs encountered during construction should be controlled by subsurface drains or other appropriate methods.

Subsurface drainage should be provided in areas having a high water table, to intercept seepage that would affect slope stability, building foundations, or create undesirable wetness.

Excavations should not be made so close to property lines as to endanger adjoining property without supporting and protecting such property from erosion, sliding, settling, or cracking.

No fill should be placed where it will slide or wash onto the premises of another or be placed adjacent to the bank of a channel so as to create bank failure or reduce the natural capacity of the stream.

Fills should consist of material from cut areas, borrow pits, or other approved sources.

Protective slopes around buildings should be planned to slope away from foundations and water supply wells to lower areas, drainage channels, or waterways. The minimum horizontal length should be 10 feet, except where restricted by property lines.

The minimum vertical fall of protective slopes should be 6 inches, except that the vertical fall at the high point at the upper end of a swale may be reduced to 3 inches, if a long slope toward a building or from a nearby high bank will not exist.

Minimum gradients should be 1/16 inch per foot (1/2 percent) for concrete or other impervious surfaces and ¼ inch per foot (2 percent) for pervious surfaces.

Maximum gradient of protective slopes should be 2 ½ inches per foot (21 percent) for a minimum of 4 feet away from all building walls, except where restricted by property lines.

All graded areas should be permanently stabilized immediately following final grading.

Site plans should show the location, slope, cut, fill, and finish elevation of the surfaces to be graded and the auxiliary practices for safe disposal of runoff water, slope stabilization, erosion control, and drainage such as waterways, lined, ditches, diversions, grade stabilization structures, retaining walls, and surface and subsurface drains.

Construction Recommendations

Areas to be graded should be cleared and grubbed of all timber, logs, brush, rubbish, and vegetable matter that will interfere with the grading operation. Topsoil should be stripped and stockpiled for use on critical disturbed areas for establishment of vegetation. Cut slopes to be topsoiled should be thoroughly scarified to a minimum depth of 3 inches prior to placement of topsoil.

Fill materials should be generally free of brush, rubbish, rocks, and stumps. Frozen materials or soft and easily compressible materials should not be used in fills intended to support buildings, parking lots, roads, conduits, or other structures.

Earth fill intended to support structural measures should to be compacted to a minimum of 90 percent of standard Proctor test density with proper moisture control, or as otherwise specified by the engineer responsible for design. Compaction of other fills should be to the density required to control sloughing, erosion or excessive moisture content. Maximum thickness of fill layers prior to compaction should not exceed 9 inches.

Grading should generally be done to a tolerance of within 0.2 foot of planned grades and elevations. Allowances may be made for topsoil, paving, or other surface installations.

All disturbed areas should be free draining, left with a neat and finished appearance, and should be protected from erosion. (See applicable vegetative standards.)

Maintenance

All slopes should be checked periodically to see that vegetation is in good condition. Any rills or damage from erosion and animal burrowing should be repaired immediately to avoid further damage.

If seeps develop on the slopes, the area should be evaluated to determine if the seep will cause an unstable condition. Subsurface drains or a gravel mulch may be required to solve seep problems.

Diversions, berms, and waterways should be checked to see that they are functioning properly. Problems found during the inspections should be repaired promptly.

Areas requiring revegetation should be repaired immediately.

Slopes should be limed and fertilized as necessary to keep vegetation healthy.

Control undesirable vegetation such as weeds and woody growth to avoid bank stability problems in the future.

References

Massachusetts Department of Environmental Protection, Office of Watershed Management, Nonpoint Source Program, ***Massachusetts Nonpoint Source Management Manual***, Boston, Massachusetts, June, 1993.

Minnick, E. L., and H. T. Marshall, ***Stormwater Management and Erosion Control for Urban and Developing Areas in New Hampshire***, Rockingham County Conservation District, August 1992.

Level Spreader

A level spreader is an excavated depression constructed at zero percent grade across a slope. The level spreader changes concentrated flow into sheet flow and then outlets it onto stable areas without causing erosion. It allows concentrated runoff to be discharged at non-erosive velocities onto natural or man-made areas that have existing vegetation capable of preventing erosion. An example would be at the outlet of a diversion or a waterway.

Where Practice Applies

- Where it can be constructed on undisturbed soils and a level lip can be installed without filling.
- Where the area directly below the spreader is stabilized by existing vegetation
- Where water will not re-concentrate immediately below the spreader, and water can be released in sheet flow down a stabilized slope without causing erosion.
- Where there is at least 100 feet of vegetated area between the spreader and surface waters.
- Where the area below the spreader lip is uniform with a slope of 10 percent or less and is stable for anticipated flow conditions.
- Where there will be no traffic over the spreader.

Advantages

- Level spreaders are relatively low cost structures designed to release small volumes of water safely.
- Level spreaders disperse the energy of concentrated flows, reducing erosion potential and encouraging sedimentation.

Disadvantages/Problems

If the level spreader has any low points, flow tends to concentrate there. This concentrated flow can create channels and cause erosion. If the spreader serves as an entrance to a water quality treatment system, short-circuiting of the forebay may happen and the system will be less effective in removing sediment and particulate pollutants.

Planning Considerations

Diversions and waterways need a stable outlet for concentrated stormwater flows. The level spreader can be used for this purpose if the runoff is relatively free of sediment. If properly constructed, the level spreader will significantly reduce the velocity of concentrated stormwater and spread it uniformly over a stable undisturbed area.

Placement of the level spreader must allow the water flowing over the level section to leave the structure as a uniform, thin film of water. The structure should outflow onto naturally vegetated areas whenever possible. The creation of a uniform level lip for the water to spread over is critical.

Particular care must be taken during construction to ensure that the lower lip of the structure is level. If there are any depressions in the lip, flow will tend to concentrate at these points and erosion will occur, resulting in failure of the outlet. This problem may be avoided by using a grade board or a gavel lip over which the runoff must flow when exiting the spreader. Regular maintenance is essential for this practice.

Water containing high sediment loads should enter a sediment trap before release in a level spreader.

Design Recommendations

Drainage area should be limited to five acres.

The grade of the channel for the last 20 feet of the conservation practice entering the level spreader should be no steeper than 1 percent.

The level spreader should be flat ("0 percent" grade) to ensure uniform spreading of storm runoff.

The design length for a level spreader should be no more than 0.5 cfs per foot of level section, based on the peak rate of flow from the contributing erosion control or stormwater management practice. The minimum length of the spreader should be 5 feet and the maximum length 50 feet.

The width of the spreader should be at least 6 feet.

The depth of the spreader as measured from the lip should be at least 6 inches and it should be uniform across the entire length.

The spreader shall be stabilized with an appropriate grass mixture. The spreader should be mulched if necessary for the establishment of good quality vegetation.

The level lip may be protected with an erosion stop and jute or excelsior matting. The erosion stop should be placed vertically a minimum of six inches deep in a slit trench one foot back from the crest of the level lip and parallel to the lip. The erosion stop should extend the entire length of the level lip. Two strips of jute or excelsior matting can be placed along the lip. Each strip should overlap the erosion stop by at least six inches.

The area downslope should have a complete vegetative cover sufficiently established to be erosion resistant.

Maintenance

- The level spreader should be checked periodically and after every major storm.
- Any detrimental sediment accumulation should be removed.
- If rilling has taken place on the lip, the damage should be repaired and re-vegetated.
- Vegetation should be mowed occasionally to control weeds and encroachment of woody vegetation. Clippings should be removed and disposed of outside the spreader and away from the outlet area.
- Fertilization should be done as necessary to keep the vegetation healthy and dense.
- The spreader should be inspected after every runoff event to ensure that it is functioning correctly.

References

Massachusetts Department of Environmental Protection, Office of Watershed Management, Nonpoint Source Program, ***Massachusetts Nonpoint Source Management Manual***, Boston, Massachusetts, June, 1993.

Minnick, E. L., and H. T. Marshall, ***Stormwater Management and Erosion Control for Urban and Developing Areas in New Hampshire***, Rockingham County Conservation District, August 1992.

Washington State Department of Ecology, ***Stormwater Management Manual for the Puget Sound Basin***, Olympia, WA, February, 1992.

Mulch and Netting

Application of a protective blanket of straw or other plant residue, gravel or synthetic material to the soil surface.

Purpose

To provide immediate protection to exposed soils during the period of short construction delays, or over winter months through the application of plant residues, or other suitable materials, to exposed soil areas.

Mulches also enhance plant establishment by conserving moisture and moderating soil temperatures. Mulch helps hold fertilizer, seed, and topsoil in place in the presence of wind, rain, and runoff and maintains moisture near the soil surface.

In addition to stabilizing soils, mulching can reduce the speed of storm water runoff over an area.

Where Practice Applies

- In areas which have been seeded either for temporary or permanent cover, mulching should immediately follow seeding.
- Areas which cannot be seeded because of the season, or are otherwise unfavorable for plant growth.
- Mulch around plantings of trees, shrubs, or ground covers to stabilize the soil between plants.
- In an area of greater than 2:1 slope, mulching should immediately follow seeding.

Advantages

- Mulching offers instant protection to exposed areas.
- Mulches conserve moisture and reduce the need for irrigation.
- Neither mulching nor matting require removal; seeds can grow through them unlike plastic coverings.
- This is one of the most important, effective, and economical erosion-control practices.

Disadvantages/Problems

- Care must be taken to apply mulch at the specified thickness, and on steep slopes mulch must be supplemented with netting.
- Thick mulches can reduce the soil temperature, delaying seed germination.
- Mulch can be easily blown or washed away by runoff if not secured.
- Some mulch materials such as wood chips may absorb nutrients necessary for plant growth.
- Mulches such as straw, which are often applied to areas after grading must then be removed and either composted or landfilled.

Planning Considerations

Mulches are applied to the soil surface to conserve a desirable soil property or to promote plant growth. A surface mulch is one of the most effective means of controlling runoff and erosion on disturbed land.

Mulches can increase the infiltration rate of the soil, reduce soil moisture loss by evaporation, prevent crusting and sealing of the soil surface, modify soil temperatures, and provide a suitable microclimate for seed germination.

Organic mulch materials, such as straw, wood chips, bark and wood fiber, have been found to be the most effective, although straw is preferred.

Wood chips and bark are effective for use around trees and shrubs.

It is important to properly anchor grass or straw mulch materials so they are not blown away by wind or washed away by flowing water.

On steep slopes and critical areas such as waterways, use netting or anchoring with mulch to hold it in place.

"Mechanical mulches" such as gravel may be used in critical areas where conditions preclude the use of vegetation for permanent stabilization.

The choice of materials for mulching will be based on the type of soil to be protected, site conditions, season, and economics. It is especially important to mulch liberally in mid-summer and prior to winter, and at locations on cut slopes and southern slope exposures.

Materials and Installation

Mulch Material	Quality Standards	Application Rate / 1,000 sq. ft.	Application Rate /Acre	Depth of Application	Remarks
Sawdust - green or composted	Free from objectionable coarse material	83-500 cu.ft.	- - -	1-7"	Most effective as a mulch around ornamentals, small fruits& other nursery stock. Requires 30-35 lbs. N/ton to prevent N deficiency while decaying mulch. One cu. ft. weighs 25 lbs.
Wood Chips or Shavings	Green or airdried. Free of objectionable material	500-900 lbs	10-20 tons	2-7 "	Has about the same use and application as sawdust, but requires less N/ton (10-12 lbs). Resistant to wind blowing. Decomposes slowly.
Wood Excelsior	Green or air-dried burred wood fibers	90 lbs (one bale)	2 tons	- - -	Decomposes slowly. Subject to some wind blowing. Packaged in 80-90 lb. bales.
Wood Fiber Cellulose (partially digested wood fibers)	Made form natural wood, usually with green dye & dispersing agent added	50 lbs	2000 lbs	- - -	Apply with hydromulcher. No tie-down required. Less erosion control provided than 2t hay or straw.
Compost or Manure	Well shredded, free of excessive coarse materials	400-600 lbs	8-10 tons	- - -	Use straw manure where erosion control is needed. May create problem with weeds. Excellent moisture conserver. Resistant to wind blowing.
Cornstalks, shredded or chopped	Airdried, shredded into 8-12" lengths	150-300 lbs	4-6 tons	- - -	Effective for erosion control,relatively slow to decompose. Excellent for mulch on crop fields. Resistant to wind blowing.

Mulch Material	Quality Standards	Application Rate / 1,000 sq. ft.	Application Rate /Acre	Depth of Application	Remarks
Gravel, crushed stone or slag	Washed, 1 1/2" max.	9 cu. yds	- - -	3'	Excellent mulch for short slopes and around woody plants and ornamentals. Frequently used over black plastic for better weed control.
Hay or Straw	Air-dried, free of undesirable seeds & materials	90-100 lbs. (2-3 bales)	2 tons (100-120 bales)	Cover about 90% of surface	Use straw where mulch is maintained for more than 3 months. Subject to wind blowing unless anchored. Most commonly used mulching material. Best microenvironment for germinating seeds.
Peat Moss	Dried, compressed free of coarse materials	200-400 cu. ft	---------	2"-4"	Most effective as a mulch around ornamentals. Subject to wind blowing unless kept wet. 100 lbs. bales (6 cu.ft.). Excellent moisture holding capacity.
Jute Twisted Yarn	Undyed, unbleached plain weave. Warp: 78 ends/yd. Weft: 41 ends/yd 60-90 lbs/roll	48"x50 yds or 48"x75 yds.	-------	-----	Use without additional mulch. Tie down as per manufacturing specification.
Excelsior Wood Fiber Mats	Interlocking web of excelsior fibers with photodegradable plastic netting	48"x100" 2-sided plastic; 48"x180" 1-sided plastic	------	-----	Use without additional mulch. Excellent for seeding establishment. Tie down as per manufacturers specs. Appox. 72 lbs/roll for Excelsior with plastic on both sides. Use 2-sided plastic for center, plastic for centerline of waterways.

Mulch Material	Quality Standards	Application Rate / 1,000 sq. ft.	Application Rate /Acre	Depth of Application	Remarks
Glass Fiber	1/4" thick, 7/16" dia. holes on 1" centers: 56 lb rolls	72'x30 yds.	----	----	Use without additional mulch. Tie down with T-bars as per manufacturers specifications.
Plastic	2-4 mils	variable	-----	-----	Use black for weed control. Effective moisture conservation and weed control for small fruits and ornamentals
Filter Fabrics	Woven or Spun	variable	------	------	------
Straw or coconut fiber or combination	Photodegradable plastic net on one or two sides	Most are 6.5'x83.5'	81 rolls	-----	Designed to tolerate higher velocity water flow, centerlines of waterways. 60 sq. yds. per roll.

Mulch Anchoring Guide

Anchoring Method or Material	Kind of Mulch To Be Anchored	How To Apply
Manual		
Peg & Twine	Hay or straw	After mulching, divide areas into blocks approximately 1 sq. yd. in size. Drive 4-6 pegs per block to within 2" to 3" soil surface. Secure mulch to surface by stretching twine between pegs in criss-cross pattern on each block. Secure twine around each peg with 2 or more turns. Drive pegs flush with soil where mowing and maintenance is plannned.
Mulch Netting	Hay or straw	Staple the light-weight paper, jute, wood fiber, or plastic nettings to soil surface according to manufacturers recommendations. Should be biodegradable. Most products not suitable for foot traffic.
Soil & Stone	Plastic	Plow a single furrow along edge of area to be covered with plastic, fold about 6" of plastic into the furrow and plow furrow slice back over plastic. Use stones to hold plastic down in other places as needed.
Cut-in	Hay or straw	Cut mulch into soil surface with square edged spade. Make cuts in contour rows spaced 18" apart. Most sucessful on contour in sandy soils

Anchoring Method or Material	Kind of Mulch To Be Anchored	How To Apply
Mechanical		
Asphalt Spray (emulsion)	Compost, wood chips, wood shavings, hay or straw	Apply with suitable spray equipment using the following rates; Asphalt emulsion: on slopes use 200 gal/acre, on level, use 150 gal/acre Liquid asphalt: (rapid, medium, or slow setting) 0.10 gal per square yd. 400 gal/acre
Wood Cellulose Fiber	Hay or straw	Apply with hydroseeder immediately after mulching. Use 750 lbs. wood fiber per acre. Some products contain an adhesive material.
Pick Chain	Hay or straw, manure compost	Use on slopes steeper than 3:1. Pull across slopes with suitable power equipment.
Mulch Anchoring tool or Disk	Hay or straw, manure/mostly straw	Apply mulch and use a mulch anchoring tool. When a disk (smooth) is used, set in straight position and pull across slope with suitable power equipment. Mulch material should be tucked into soil surface about 3".
Chemical	Hay or straw	Apply Terra Tack AR at 120 lbs/acre in 480 gal. of water or Aerospray 70 (60 gal/acre) according to manufacturer's instructions. A 24 hr. curing period and a soil temp higher than 45 degrees F. are required.

Common Trouble Points

Inadequate Coverage
Results in erosion, washout, and poor plant establishment

Appropriate tacking agent not applied, or applied in insufficient amount
Mulch is lost to wind and runoff.

Channel grade and liner not appropriate for amount of runoff
Results in erosion of channel bottom. Plan modification may be required.

Hydromulch applied in winter
Results in deterioration of mulch before plants can become established.

Maintenance

Inspect after rainstorms to check for movement of mulch or erosion. If washout, breakage, or erosion occurs, repair surface, reseed, remulch, and install new netting.

Straw or grass mulches that blow or wash away should be repaired promptly.

Blanket mulch that is displaced by flowing water should be repaired as soon as possible.

If plastic netting is used to anchor mulch, care should be taken during initial mowings to keep the mower height high. Otherwise, the netting can wrap up on the mower blade shafts. After a period of time, the netting degrades and becomes less of a problem.

Continue inspections until vegetation is well established.

References

Gaffney, F.B., Dickerson, J.A., Myers, R.E., Hoyt, D.K., Moonen, H.F., Smith, R.E., ***A Guide To: Conservation Plantings on Critical Areas for New York***, U.S. Department of Agriculture, Soil Conservation Service, Syracuse, NY, June, 1991.

Massachusetts Department of Environmental Protection, Office of Watershed Management, Nonpoint Source Program, ***Massachusetts Nonpoint Source Management Manual***, Boston, Massachusetts, June, 1993.

Minnick, E. L., and H. T. Marshall, ***Stormwater Management and Erosion Control for Urban and Developing Areas in New Hampshire,*** Rockingham County Conservation District, August 1992.

North Carolina Department of Environment, Health, and Natural Resources, ***Erosion and Sediment Control Field Manual***, Raleigh, NC, February 1991.

U. S. Environmental Protection Agency, ***Storm Water Management For Construction Activities***, EPA-832-R-92-005, Washington, DC, September, 1992.

Washington State Department of Ecology, ***Stormwater Management Manual for the Puget Sound Basin***, Olympia, WA, February, 1992.

Outlet Protection and Stabilization

A structure designed to control erosion at the outlet of a channel or conduit by reducing the velocity of flow and dissipating the energy.

Where Practice Applies

- Outlet protection should be installed at all pipe, culverts, swales, diversions, or other water conveyances where the velocity of flow may cause erosion at the pipe outlet and in the receiving channel.
- Outlet protection should also be used at outlets where the velocity of flow at the design capacity may result in plunge pools.
- Outlet protection should be installed early during construction activities, but may be added at any time, as necessary.

Advantages

- Plunge pools, which can develop unless outlet protection is provided, may severely weaken the embankment and thus threaten its stability.
- Protection can prevent scouring at a culvert mouth and thus prevent gully erosion which may gradually extend upstream.

Disadvantages/Problems

- Some types of structures may be unsightly.
- Sediment removal may be difficult.

Planning Considerations

Erosion at the outlet of channels, culverts, and other structures is common and can cause structural failure with serious downstream problems.

A riprap lined apron is the most commonly used structure for this purpose, because it has relatively low cost and can be installed easily on most sites.

Other types of outlet stabilization structures include riprap stilling basins, concrete impact basins, and paved outlets.

Design Criteria

Capacity - Peak runoff from 10-year storm.

Apron - As shown in plans, set on zero grade, aligned straight, with sufficient length to dissipate energy.

Foundation - Extra-strength filter fabric or well-graded gravel filter layer, 6 inches thick, minimum.

Material - Hard, angular, and highly weather-resistant stone (riprap) with specific gravity at least 2.5. Stone size as specified in plans.

Thickness - At least 1.5 times the maximum stone diameter.

Installation

Excavate subgrade below design elevation to allow for thickness of filter and riprap. Install riprap to minimum thickness of 1.5 times maximum stone diameter. Final structure should be to lines and elevations shown in plans.

Construct apron on zero grade. If there is no well-defined channel, cross section may be level or slightly depressed in the middle. In a well-defined channel, extend riprap and filter to the top of the bank or as shown on plans. Blend riprap smoothly to the surrounding land.

Apron should be straight and properly aligned with the receiving stream. If a curve is necessary to fit site conditions, curve the apron near the upstream end.

Compact any fill used in the subgrade to the density of the surrounding undisturbed material.

Subgrade should be smooth enough to protect fabric from tearing.

Install a continuous section of extra-strength filter fabric on smooth, compacted foundation.

Protect filter fabric from tearing while placing riprap with machinery. Repair any damage immediately by removing riprap and installing another section of filter fabric. Upstream section of fabric should overlap downstream section a minimum of one foot.

Make sure top of riprap apron is level with receiving stream or slightly below it. Riprap should not restrict the channel or produce an overfall.

Immediately following installation, stabilize all disturbed areas with vegetation as shown in plans.

Common Trouble Points

Foundation not excavated deep enough or wide enough

Riprap restricts flow cross section, resulting in erosion around apron and scour holes at outlet.

Riprap apron not on zero grade
Causes erosion downstream.

Stones too small or not properly graded
Results in movement of stone and downstream erosion.

Riprap not extended far enough to reach a stable section of channel
Results in downstream erosion.

Appropriate filter not installed under riprap
Results in stone displacement and erosion of foundation.

Maintenance

Inspect riprap outlet structures after heavy rains for erosion at sides and ends of apron and for stone displacement.

Rock may need to be added if sediment builds up in the pore spaces of the outlet pad.

Make repairs immediately using appropriate stone sizes. Do not place stones above finished grade.

References

Massachusetts Department of Environmental Protection, Office of Watershed Management, Nonpoint Source Program, Massachusetts ***Nonpoint Source Management Manual Boston***, Massachusetts, June, 1993.

North Carolina Department of Environment, Health, and Natural Resources, ***Erosion and Sediment Control Field Manual,*** Raleigh, NC, February 1991.

U. S. Environmental Protection Agency, ***Storm Water Management for Construction Activities***, EPA-832-R-92-005, Washington, DC, September, 1992.

Washington State Department of Ecology, ***Stormwater Management Manual for the Puget Sound Basin***, Olympia, WA, February, 1992

Preserving Natural Vegetation

Minimizing exposed soils and consequent erosion by clearing only where construction will occur.

Where Practice Applies

Natural vegetation should be preserved whenever possible, but especially on steep slopes, near perennial and intermittent watercourses or swales, and on building sites in wooded areas.

Advantages

Preserving natural vegetation will:

- Save money on site stabilization
- Help reduce soil erosion.
- Beautify an area.
- Save money on landscaping costs.
- Provide areas for wildlife.
- Possibly increase the value of the land.
- Provide buffers and screens against noise.

Preserving natural vegetation also moderates temperature changes and provides shade and cover habitat for surface waters and land. Increases in stream water temperature tend to lower the dissolved oxygen available for aquatic life.

Disadvantages/Problems

Saving individual trees can be difficult, and older trees may become a safety hazard.

Planning Considerations

New development often takes place on tracts of forested land. Building sites are often selected because of the presence of mature trees. Unless sufficient care is taken and planning done, however, much of this resource is likely to be destroyed in the interval between buying the property and completing construction. It takes 20 to 30 years for newly planted trees to provide the benefits for which we value trees so highly.

Natural vegetation can be preserved in natural clumps or as individual trees, shrubs and vines.

Selection

Examine the area to identify trees to be saved: trees with unique or unusual form, trees which may be uncommon in the area, desirable shade trees and trees for screening purposes. Look for healthy trees with full green crowns. The length of the annual twig growth gives an indication of the general vigor of the tree. Trees with broken tops or with many dead branches are usually not good risks. Badly scarred trees are also unsuitable.

In selecting trees to be retained, care must also be used to make certain they will not interfere with the installation and maintenance of utilities such as electric and telephone lines, water and sewer lines and driveways.

Preserving individual plants is more difficult because equipment is generally used to remove unwanted vegetation. Points to consider when attempting to save individual plants are:

Value

Is the plant worth saving? Consider the location, species, size, age, vigor, and the work involved. Local governments may also have ordinances to save natural vegetation and trees.

Desirability

Is the tree or shrub a desirable plant? Is it shallow-rooted, do the roots seek water, or are insects and disease a problem? Shallow-rooted plants can cause problems in the establishment of lawns or ornamental plants. Water-seeking roots can block sewer and tile lines. Insects and diseases can make the plant undesirable. This is especially true with aphids on alder and maple.

Age and size

Old or large plants do not generally adapt to changes in environment as readily as young plants of the same species. Usually, it is best to leave trees which are less than 40 years of age. Some hardwoods mature at approximately 50 years of age. After maturity they rapidly decline in vigor. Conifers, after 40 years of age, may become a safety hazard due to the possibility of breakage or blowdown, especially where construction has left only a few scattered trees in an area that was formerly dense woods.

While old large trees are sometimes desirable, the problem of later removal should be considered. Local governments, however, may have requirements to preserve older, larger specimen trees. It is expensive to cut a large tree and to remove the tree and stump from a developed area. Thinning some branches from trees can provide avenues for wind and hence lessen the “sail” effect.

Tree Preservation

Clearly flag or mark areas around trees that are to be saved. It is preferable to keep ground disturbance away from the trees at least as far out as the dripline.

Barriers

If possible, place a barrier around the trees. Bulldozers are notorious for damaging trees. Besides skinning bark from tree trunks, their tracks severely damage tree roots which are close to the surface.

Place a simple wooden fence around the tree. Inexpensive or scrap lumber will do. Snow fencing, although more expensive, is easy to install. The fence should enclose an area at least five feet out from the tree trunk. Erect the fence before the bulldozer arrives and leave it up until the last piece of equipment has left the area.

Marking

If erecting a barrier around the trees is impractical, marking the trees may help save them from damage, if equipment operators are forewarned and reliable. A band of bright colored cloth, ribbon, or tape may be used to identify trees to be protected. The band should be placed around the trunk high enough to be seen from a distance and from all angles. It is important that all people involved be informed of the meaning of the marking.

Grade Changes

Filling

Tree roots need air water and minerals to survive. Few trees can survive with more than six inches of earth fill over the roots. The tree roots are literally suffocated with more earth fill than this coarser the fill material, the better the chance for survival.

Construction of a dry well around the tree trunk will provide some air circulation for the trees. Installation of a drain system in conjunction with the dry well is even better. Four inch drain pipe is placed in a spoke-like fashion to drain water away from the tree before filling takes place.

The dry well may be built of stones, brick, tile, concrete blocks or other material. It should be built at least 12 to 18 inches away from the trunk of a large, slow-growing tree and up to 36 inches for younger fast-growing trees.

Lowering

Lowering the natural ground level can seriously damage trees and shrubs. Most of the plant roots are in the upper 12 inches of the soil and cuts of only 2-3 inches can cause serious injury. To protect the roots it may be necessary to terrace the immediate area around the plants to be saved. If roots are exposed, construction of retaining walls may be needed to keep the soil in place. Plants can also be preserved by leaving them on an undisturbed, gently sloping mound. To increase the chances for survival, it is best to limit grade changes and other soil disturbances to areas outside the dripline of the plant.

Excavations

Protect trees and other plants when excavating for tile, water, and sewer lines. Where possible, the trenches should be routed around trees and large shrubs. When this is not possible, it is best to tunnel under them. This can be done with hand tools or with power augers.

If it is not possible to route the trench around plants to be saved, then the following should be observed:

- Cut as few roots as possible. When you have to cut - cut clean. Paint cut root ends with a wood dressing like asphalt base paint.
- Backfill the trench as soon as possible.
- Tunnel beneath root systems as close to the center of the main trunk as possible to preserve most of the important feeder roots.

Common Trouble Points

Some problems that can be encountered with trees are:

- Maple, Dogwood, Eastern hemlock, Eastern red cedar and Douglas fir do not readily adjust to changes in environment and special care should be taken to protect these trees.
- Maples, and willows have water-seeking roots. These can cause trouble in sewer lines and filter fields. On the other hand, they thrive in high moisture conditions that other trees would succumb to.

- Thinning operations can cause serious disease problems. Disease can become established through damaged limbs, trunks, roots, and freshly cut stumps. Diseased and weakened trees are also susceptible to insect attack.

Maintenance

Inspect flagged areas regularly to make sure flagging has not been removed. If tree roots have been exposed or injured, re-cover and/or seal them.

References

Washington State Department of Ecology, ***Stormwater Management Manual for the Puget Sound Basin***, Olympia, WA, February, 1992.

U.S. Department of Agriculture, Soil Conservation Service, Amherst, MA, ***Guidelines for Soil and Water Conservation in Urbanizing Areas of Massachusetts***, October, 1977.

Riprap

A permanent, erosion-resistant ground cover of large, loose, angular stone.

Purpose

- To protect slopes, streambanks, channels, or areas subject to erosion by wave action.
- Rock riprap protects soil from erosion due to concentrated runoff. It is used to stabilize slopes that are unstable due to seepage. It is also used to slow the velocity of concentrated runoff which in turn increases the potential for infiltration.

Where Practice Applies

- Cut or fill slopes subject to seepage or weathering, particularly where conditions prohibit establishment of vegetation,
- Channel side slopes and bottom,
- Inlets and outlets for culverts, bridges, slope drains, grade stabilization structures, and storm drains; where the velocity of flow from these structures exceeds the capacity of the downstream area to resist erosion.
- Stream banks and stream grades,
- Shorelines subject to wave action.

Advantages

- Riprap offers an easy-to-use method for decreasing water velocity and protecting slopes from erosion. It is simple to install and maintain.
- Riprap provides some water quality benefits by increasing roughness and decreasing the velocity of the flow, inducing settling.

Disadvantages/Problems

- Riprap is more expensive than vegetated slopes.
- There can be increased scour at the toe and ends of the riprap.
- Riprap does not provide the habitat enhancement that vegetative practices do.

Planning Considerations

Well graded riprap forms a dense, flexible, self-healing cover that will adapt well to uneven surfaces.

Care must be exercised in the design so that stones are of good quality, sized correctly, and placed to proper thickness.

Riprap should be placed on a proper filter material of sand, gravel, or fabric to prevent soil from “piping” through the stone.

Contact the local Conservation Commission regarding any stream crossing or other work conducted in a wetland resource area. The Massachusetts Wetland Protection Act requires that the proponent file a “Determination of Applicability” or “Notice of Intent.”

Rock riprap is used where erosion potential is often high. The rock should be placed as soon as possible after disturbing the site, before additional water is concentrated into the drainage system. Properly sized bedding or geotextile fabric is needed to prevent erosion or undermining of the natural underlying material.

Riprap is classified as either graded or uniform. A sample of graded riprap would contain a mixture of stones which vary in size from small to large. A sample of uniform riprap would contain stones which are all fairly close in size.

For most applications, graded riprap is preferred to uniform riprap. Graded riprap forms a flexible self-healing cover, while uniform riprap is more rigid and cannot withstand movement of the stones. Graded riprap is cheaper to install, requiring only that the stones be dumped so that they remain in a well-graded mass. Hand or mechanical placement of individual stones is limited to that necessary to achieve the proper thickness and line. Uniform riprap requires placement in a more or less uniform pattern, requiring more hand or mechanical labor.

Design Recommendations

As graded riprap consists of a variety of stone sizes, a method is needed to specify the size range of the mixture of stone. This is done by specifying a diameter of stone in mixture for which some percentage, by weight, will be smaller. For example, d 85 refers to a mixture of stones in which 85 percent of the stone by weight would be smaller than the diameter specified. Most designs are based on "d." The design, therefore, is based on the median size of stone in the mixture.

A well graded mixture of rock sizes should be used for riprap rather than rocks of a uniform size. Rock riprap sizes are specified by either weight or diameter.

Stone should be hard, angular, weather-resistant; specific gravity at least 2.5.

Gradation: well-graded stone, 50% by weight larger than the specified "150" The largest stones should not exceed 1.5 times the "d5O" specified. Stones should be shaped so that the least dimension of the stone fragment is not less than one-third of the greatest dimension of the fragment. Flat rocks should not be used for riprap.

Filter: heavy-duty filter fabric or aggregate layer should be used under all permanent riprap installations.

Thickness: 1.5 times the maximum stone diameter, minimum, or as specified in the plan.

Construction Recommendations

Subgrade for the filter material, geotextile fabric or riprap should be cleared and grubbed to remove all roots, vegetation, and debris and prepared to the lines and grades shown on the plans.

Excavate deep enough for both filter and riprap. Compact any fill material to the density of surrounding undisturbed soil.

Excavate a keyway in stable material at base of slope to reinforce the toe. Keyway depth should be 1.5 times the design thickness of riprap and should "extend a horizontal distance equal to the design thickness.

Rock and/or gravel used for filter and riprap shall conform to the specified gradation.

Voids in the rock riprap should be filled with spalls and smaller rocks.

Filter

Install synthetic filter fabric or a sand/gravel filter on subgrade.

Synthetic filter fabric

Place filter fabric on a smooth foundation. Overlap edges at least 12 inches, with anchor pins spaced every 3 ft along overlap. For large stones, a 4-inch layer of sand may be needed to protect filtercloth.

Geotextile fabrics should be protected from puncture or tearing during placement of the rock riprap by placing a cushion of sand and gravel over the fabric. Damaged areas in the fabric should be repaired by placing a piece of fabric over the damaged area or by complete replacement of the fabric. All overlaps required for repairs or joining two pieces of fabric should be a minimum of 12 inches.

Sand/gravel filter

Spread well-graded aggregate in a uniform layer to the required thickness (6 inches minimum). If two or more layers are specified, place the layer of smaller stones first and avoid mixing the layers.

Stone Placement

Place riprap immediately after installing filter.

Install riprap to full thickness in one operation. Do not dump through chutes or use any method that causes segregation of stone sizes. Avoid dislodging or damaging underlying filter material when placing stone.

If fabric is damaged, remove riprap and repair fabric by adding another layer, overlapping the damaged area by 12 inches.

Place smaller stones in voids to form a dense, uniform, well-graded mass. Selective loading at the quarry and some hand placement may be necessary to obtain an even distribution of stone sizes.

Blend the stone surface smoothly with the surrounding area allowing no protrusions or overfall.

Since riprap is used where erosion potential is high, construction must be sequenced so that the riprap is put in place with the minimum possible delay. Disturbance of areas where riprap is to be placed should be undertaken only when final preparation and placement of the riprap can follow immediately behind the initial disturbance.

Where riprap is used for outlet protection, the riprap should be placed before or in conjunction with the construction of the pipe or channel so that it is in place when the pipe or channel begins to operate.

Common Trouble Points

Excavation not deep enough

Riprap blocks channel, resulting in erosion along edges.

Slope too steep

Results in stone displacement. Do not use riprap as a retaining wall.

Foundation not properly smoothed for filter placement

Results in damage to filter.

Filter omitted or damaged

Results in piping or slumping.

Riprap not properly graded
Results in stone movement and erosion of foundation.

Foundation toe not properly reinforced
Results in undercut riprap slope or slumping.

Fill slopes not properly compacted before placing riprap
Results in stone displacement.

Maintenance

Riprap should be checked at least annually and after every major storm for displaced stones, slumping, and erosion at edges, especially downstream or downslope. If the riprap has been damaged, it should be repaired immediately before further damage can take place.

Woody vegetation should be removed from the rock riprap annually because tree roots will eventually dislodge the riprap.

If the riprap is on a channel bank, the stream should be kept clear of obstructions such as fallen trees, debris, and sediment bars that may change flow patterns which could damage or displace the riprap.

References

Massachusetts Department of Environmental Protection, Office of Watershed Management, Nonpoint Source Program, Massachusetts ***Nonpoint Source Management Manual***, Boston, Massachusetts, June, 1993.

Minnick, E. L., and H. T. Marshall, ***Stormwater Management and Erosion Control for Urban and Developing Areas in New Hampshire*** , Rockingham County Conservation District, August 1992.

North Carolina Department of Environment, Health, and Natural Resources, ***Erosion and Sediment Control Field Manual,*** Raleigh, NC, February 1991.

Washington State Department of Ecology, ***Stormwater Management Manual for the Puget Sound Basin***, Olympia, WA, February, 1992.

Rock Dam

A rock embankment constructed across a drainageway or other suitable location to create a temporary basin for collecting sediment.

Purpose

To trap sediment on the construction site and prevent off-site sedimentation. Useful where earth fill material is not readily available.

Where Practice Applies

Where a temporary measure is needed to retain sediment from a construction area - but not in a natural stream.

Design Criteria

Drainage area: limited to 50 acres.

Design life: limited to 3 years.

Sediment storage: 1800 cubic feet per acre disturbed, as a minimum. Measured one foot below spillway crest.

Dam crest height: limited to 8 feet.

Basin area and shape: The largest surface area gives the greatest trapping efficiency. Basin length-to-width ratio should be 2:1 minimum.

Spillway capacity: 10-year peak runoff, at maximum flow depth of one foot and minimum freeboard of one foot. Entire length of dam between rock abutments may serve as spillway.

Rock embankment:

Top width	5 ft minimum
Side slopes	Upstream, 2:1 or flatter; Downstream, 3:1 or flatter
Earth abutments	Smooth, stable slopes, 2:1 or flatter.

Rock abutments Must protect earth abutments and extend along downstream face to toe of dam. Abutments must be at least one foot higher than the spillway face at all points.

Height	2 ft minimum above spillway crest
Width	2 ft thick, minimum
Side slopes	2:1 or flatter

Outlet protection: Rock apron, 1.5 ft thick, minimum, zero grade, length equal to height of dam or extended to stable grade, whichever is greater.

Rock material: Well-graded, hard, angular, weather-resistant stone with a “d50” of 9 inches minimum.

Protection from piping: Extra-strength filter fabric covering entire foundation including earth abutments and apron.

Basin dewatering: Through one-foot thick minimum layer of ½- to ¾-inch aggregate on upstream face of dam.

Installation

Divert runoff from undisturbed areas away from the basin. Delay clearing pond area until dam is in place.

Excavate foundation for apron and use it as a temporary sediment basin during construction of dam.

Clear and grub area under darn, removing all root mat and other objectionable material. Grade earth abutments no steeper than 1:1. Dispose of material in approved location.

If cutoff trench is required, excavate at center line of dam, extending all the way up earth abutments.

Protection from Piping

The entire foundation including both earth abutments must be covered by filter fabric. Overlap one foot at all joints, upstream strip over downstream strip.

Smooth the foundation area before placing filter fabric. Be careful placing rock on fabric. It may be helpful to place a 4-inch layer of sand over fabric before placing rock.

Embankment and pool

Construct embankment to dimensions shown on plans. Use well-graded, hard, angular, weather-resistant rock. Rock abutments must be at least 2 feet higher than the spillway crest and at least 1 foot higher than the downstream face of dam at all points.

Divert sediment-laden flow to upper end of basin.

Set marker stake to indicate clean out elevation where sediment pool is 50% full.

Establish vegetation to stabilize all disturbed areas except the lower one-half of sediment pool as shown in the plan.

Safety

Sediment basins that impound water are hazardous. Basin should be dewatered between storms. Avoid steep side slopes. Fences with warning signs may be necessary if trespassing is likely. State and local requirements must be followed.

Common Trouble Points

Failure from piping along abutments
Filter material not properly installed, or earth abutments too steep.

Stone displaced from face of dam
Stone size too small and/or face too steep.

Erosion below dam
Apron not extended to stable grade.

Erosion of abutments during spillway flow
Rock abutment height inadequate.

Sediment carried through spillway
Drainage area too large. Divert runoff from undisturbed area away from basin.

Sediment loss through dam
Inadequate layer of aggregate on inside face or aggregate too coarse to restrict flow through dam.

Maintenance

- Inspect rock dam and pool after each rainfall event.
- Remove sediment when it accumulates to one-half design volume (marked by stakes).
- Check structure and abutments for erosion, piping, or rock displacement. Repair immediately.
- Replace aggregate on inside face of structure when sediment pool does not drain between storms.
- Add fine gravel to upstream face of dam if sediment pool drains too rapidly (less than 6 hours) following a storm.
- Remove rock dam after the contributing drainage area has been permanently stabilized, inspected, and approved. Remove all water and sediment prior to removing dam. Dispose of waste materials in designated disposal areas. Smooth site to blend with surrounding area and stabilize according to vegetation plan.

References

North Carolina Department of Environment, Health, and Natural Resources, ***Erosion and Sediment Control Field Manual***, Raleigh, NC, February 1991.

Massachusetts Department of Environmental Protection, Office of Watershed Management, Nonpoint Source Program, ***Massachusetts Nonpoint Source Management Manual, Boston***, Massachusetts, June, 1993.

Sand Dune and Sandblow Stabilization

Planning Considerations

Active sand areas may be stabilized by establishing temporary control measures, followed by tree or shrub planting within five years. In situations where trees or shrubs are not desired or practical, such as the seaface of a beach frontal dune, American beachgrass may be maintained as a long-term means of stabilization.

Methods of Stabilization

Mechanical - This is usually done with brush matting or with sand fencing. It is usually limited to small areas where beachgrass is not available for planting, or where immediate stabilization is desired.

Place brush matting (preferably coniferous) with butts to windward. Start placing on leeward side, working towards windward side. Overlap butts with tops to provide a shingling effect. Sand fencing placed at right angles to the prevailing wind will also give temporary stabilization but is expensive and more prone to vandalism.

Beachgrass - Beachgrass may be a temporary or long-term measure. American beachgrass is planted in culms. Culms should consist of two or more healthy stems, 2 to 3 feet tall. The ideal time to plant dormant beachgrass culms is in early spring, March 15 to May 1. Culms should be planted 8 to 9 inches deep. Culms may be dug anytime during the planting season. The stems should be cut back to 12 to 15 inches before or after digging. They may be stored by heeling-in, or storing at 28 to 32 degrees F.

Culm plantings should be planted at 18 inch spacings, with center staggered in alternate rows. Five hundred to 1,000 pounds per acre of 10-5-5, or equivalent analysis, should be applied soon after planting, or in the case of a fall planting, the fertilizer should be applied early the following spring.

An alternative, less expensive method, is to plant the beachgrass in bands. These bands should be spaced 20 to 40 feet apart. The bands should consist of at least 2 rows spaced approximately 18 inches apart, with culms approximately 18 inches apart in the rows and centers staggered in alternate rows. The closer band spacing should be used on the windward side. Fertilizer should be applied to the planted bands as indicated above.

When beachgass is to be used for long-term protection, it may be maintained by annual applications of 300-500 pounds per acre of a 10-5-5 fertilizer or its equivalent.

References

North Carolina Department of Environment, Health, and Natural Resources, ***Erosion and Sediment Control Field Manual***, Raleigh, NC, February 1991.

Tree Plantings for Enduring Cover Species

Inland Areas	Coastal Areas
Eastern red cedar*	Pitch pine

Density and Arrangement:
400-1,000 plants per acre uniformly spaced. Trees should be planted where existing vegetation is least competitive.

Shrub Plantings for Enduring Cover
Species

Inland Areas	Coastal Areas
Bayberry	Beach plum
Eastern red cedar*	Bayberry
Rugosa rose	Rugosa rose

Density and Arrangement
Plant in rows or uniform spacing with 4 to 6 feet between plants.

**Caution to users who may be near orchards: Eastern red cedar is an alternate host to apple rust.*

Sand Fence

An artificial barrier of evenly spaced wooden slats or synthetic fabric erected perpendicular to the prevailing wind and supported by posts.

Sand fences are usually made commercially of light wooden slats wired together with spaces between the slats. The distance between slats is approximately equal to the slat width (about 1 ½ inches). Synthetic fencing fabric is available for this use. The fences are erected 2 to 4 feet high in parallel rows spaced 30 to 40 feet apart over the area to be protected. Fences are supported by wooden or metal posts.

Purpose

To reduce wind velocity at the ground surface and trap blowing sand. Typically used for rebuilding frontal dunes along coastal areas.

Where Practice Applies

- Across open bare, sandy soil areas subject to frequent winds, where the trapping of blowing sand is desired.
- Wind fences are used primarily to build frontal ocean dunes (to control erosion from wave overwash and flooding).
- Sand fences can also be used to prevent sand from blowing off disturbed areas onto roads or adjacent property.

Planning Considerations

When wind fences are approximately two-thirds full, another series of fences is erected. In this manner, dunes can be built 2 to 6 feet high or more during a single season. When the dune has reached the approximate height of other mature dunes or when the building process slows significantly, stabilize with appropriate vegetation.

Installation

Install sand fences in spring or early summer and seed selected permanent vegetation in the fall or the following spring.

Erect a windward fence parallel to existing dune (generally perpendicular to the prevailing onshore wind), at least one foot above the maximum annual high water elevation. Locate a second fence generally parallel to the first at the top edge of the eroded dune bank. Space additional parallel fences 30 - 40 feet apart as needed over the area to be built up.

A second set of fences may be erected perpendicular to the first to protect captured dune sand from cross winds. Space perpendicular fences a greater distance apart (50-75 feet).

Support fencing material with 2 x 4-inch or 3-inch round posts, 6 feet long minimum, driven firmly into the ground at least 2 feet and spaced approximately 12 feet apart. Alter spacing so that posts are placed at all low points. Secure fencing to windward side of posts by tying or nailing. Press bottom of fencing material firmly into the ground at all points.

Raising the Dune

When the fence system is approximately two-thirds filled with sand, erect another series of fences until desired dune height is reached.

Final Stabilization

When the dune-building process slows significantly, the dune must be permanently stabilized. Planting should begin in November and be completed the following spring even if the dune has not reached the desired height. Vegetation hastens the building process. Maintain fences until vegetation is well established.

Common Trouble Points

Bottom fence located too low
Fence washes out.
Fences not maintained long enough
Some seasons provide little opportunity for dune building and fences may have to be maintained for longer periods.
Dune not adequately stabilized with permanent vegetation
Dune is subject to erosion during storms, even with sand fences in place.
Fencing material placed on leeward side of posts or not adequately secured
Sections of fence collapse.
Posts not driven deep enough
Fence collapses.
Fence system located too near the ocean
Not enough sand source for dune building.

Maintenance

Inspect sand fences periodically, and immediately following storms. Repair damaged sections of fence promptly.

Maintain fences until vegetation is well established.

References

Massachusetts Department of Environmental Protection, Office of Watershed Management, Nonpoint Source Program, Massachusetts ***Nonpoint Source Management Manual Boston***, Massachusetts, June, 1993.

North Carolina Department of Environment, Health, and Natural Resources, ***Erosion and Sediment Control Field Manual***, Raleigh, NC, February 1991.

Sediment Basin

A sediment basin is a settling pond with a controlled storm water release structure used to collect and store sediment produced by construction activities. A sediment basin can be constructed by excavation or by placing an earthen embankment across a low area or drainage swale. Sediment basins can be designed to maintain a permanent pool or to drain completely dry. The basin detains sediment-laden runoff long enough to allow most of the sediment to settle out.

Purpose

- To collect and store sediment from sites cleared and/or graded during construction or for extended periods of time before reestablishment of permanent vegetation or construction of structures.
- To retain sediment on the construction site and prevent off-site sedimentation.

Where Practice Applies

Sediment basins are needed where other erosion control measures are not adequate to prevent offsite sedimentation.

A sediment basin should be used only where is sufficient space and appropriate topography. The basin should be made large enough to handle the maximum expected amount of site drainage.

Fencing around the basin may be necessary for safety or vandalism reasons.

A sediment basin used in combination with other control measures, such as seeding or mulching, is especially effective for removing sediments.

Dam Safety Regulations must be followed where applicable.

Advantages

Protects downstream areas from clogging or damage due to sediment deposits generated during construction activities.

Because of additional detention time, sediment ponds may be capable of trapping smaller-sized sediment particles than other practices. They are most effective, however, when used in conjunction with other practices such as seeding or mulching.

Disadvantages/Problems

Ponds may become an “attractive nuisance” and a safety hazard.

Sediment ponds are only effective in removing sediment down to about the medium silt size fraction. Sediment-laden runoff with smaller-size fractions (fine silt and clay) will pass through untreated; emphasizing the need control erosion to the maximum extent first.

Planning Considerations

Sediment basins are usually constructed by building a low earthen dam across a drainageway to form a temporary sediment storage pool. A properly designed spillway outlet with adequate freeboard is essential.

A sediment basin may be created by excavation, construction of a compacted embankment, or a combination of both. It may have one or more inflow points carrying polluted runoff.

Basins should be installed before clearing and grading begin.

To improve trap efficiency the basin should have the maximum surface area possible, and sediment should enter the basin as far from the outlet as possible.

Sediment basin life should be limited to 3 years, unless it is designed as a permanent structure.

Effectiveness

Sediment basins are at best only 70-80 percent effective in trapping sediment which flows into them. Therefore, they should be used in conjunction with erosion control practices such as temporary seeding, mulching, diversion dikes, etc. to reduce the amount of sediment flowing into the basin. Sediment basins are most effective when designed with a series of chambers.

Location

Locate sediment basins only in upland areas, not wetlands.

Ensure that basin location provides a convenient concentration point for sediment laden flows from the area served.

To improve the effectiveness of the basin, it should be located so as to intercept the largest possible amount of runoff from the disturbed area. The best locations are generally on relatively flat terrain downstream from disturbed areas.

Drainage into the basin can be improved by the use of diversion dikes and ditches.

The basin must not be located in a stream but should be located to trap sediment-laden runoff before it enters the stream.

The basin should not be located where its failure would result in the loss of life or interruption of the use or service of public utilities or roads.

Diversions

Divert sediment-laden water to upper end of sediment pool to improve trap effectiveness. Bring all water into the basin at low velocity to prevent erosion.

Divert runoff from undisturbed areas away from basin.

Multiple Use

Sediment basins may be designed as permanent structures to remain in place after construction is completed for use as stormwater detention ponds. Sediment must be removed from the pond when construction is complete to prepare the pond for permanent use.

Design Recommendations

Drainage area - Not more than 100 acres.

Sediment storage - The sediment basin should have a minimum volume based on ½ inch of storage for each acre of drainage area. This volume equates to 1800 cubic feet of storage or 67 cubic yards for each acre of drainage area.

Trap efficiency - Length-to-width ratio should be 2:1 or greater; divert inflow to upper end of basin to avoid short-circuiting flow. Length is defined as the average distance from the inlet to the outlet of the trap. Baffles to spread the flow throughout the basin should be included.

Dewatering - Perforate riser and cover holes with gravel.

Total spillway capacity -10-year peak flow with 1 foot freeboard.

Principal Spillway

Riser and barrel - Usually vertical pipe riser with horizontal pipe barrel; must withstand the maximum external loading without yielding, buckling, or cracking. Pipe connections must be watertight.

Capacity Minimum of 0.2 cfs/acre of drainage.

Barrel diameter - 8-inch corrugated pipe minimum, or 6-inch smooth-wall pipe minimum.

Riser cross-sectional area - 1.5 x barrel area, minimum.

Dewatering - Perforate lower half of riser in each outside valley with ½-inch holes spaced approximately 3 inches. If corrugated pipe is used, locate holes along each outside valley. Cover with 2 ft of ½- to ¾-inch aggregate.

Crest of principal spillway - One foot minimum below elevation of emergency spillway crest.

Seepage prevention - At least one watertight antiseep collar with a minimum projection of 2 feet is required around barrel of pipes 8 inches in diameter or larger. The antiseep collar(s) shall increase by 15 percent the seepage path along the pipe from the riser to downstream toe of dam.

Anti-flotation block - Riser must be held in place with an anchor having buoyant weight greater than 1.1 times the weight of water displaced by riser and any exposed portion of barrel.

Trash guard - Required at top of riser.

Outlet - Must be stable for design pipe discharge. Install riprap outlet apron unless foundation is rock.

Emergency Spillway

Capacity - 10-year peak flow, minus flow in principal spillway.

Location - Construct in undisturbed soil - not fill.

Cross section - Trapezoidal with side slopes 3:1 or flatter.

Control section - Level and straight, at least 20 feet long. Outlet section must be straight.

Embankment - Top width 8 feet minimum for dam height less than 10 feet. 10 feet minimum for dam height of 10 to 15 feet.

Side slopes - 2.5:1 or flatter.

Settlement allowance - 10% of design height.

Cutoff trench - Required tinder centerline of dam, depth 2 feet minimum into undisturbed firm mineral soil. Extend trench up each abutment to elevation of emergency spillway crest. The bottom width should be wide enough to permit operation of excavation and compaction equipment, but not less than 4 feet wide. Side slopes should be no steeper than 1:1.

Fill material - The fill material should be clean mineral soil free of roots, woody vegetation, oversized stones, rocks, or other objectionable material. Relatively pervious materials such as sand or gravel (Unified Soil Classification GW, GP, SW, and SP) should not be used in the fill.

Freeboard - “Freeboard” is the difference between the design flow elevation in the emergency spillway and the top elevation of the embankment. Minimum freeboard should be one foot.

Construction Recommendations

Site Preparation

The sediment basin should be as close to the sediment source as site conditions allow considering soils, pool area, dam length, and spillway conditions. Delay clearing pool until dam is complete to reduce erosion and off-site sedimentation.

Clear, grub, and strip dam location. Excavate area for the outlet apron.

Remove surface soil containing high amounts of organic matter and stockpile for later use. Clear sediment pool to facilitate sediment cleanout.

Dispose of trees, limbs, logs, and other debris in designated disposal areas.

Cutoff Trench

Excavate cutoff trench along dam centerline extending up both abutments to elevation of principal spillway crest.

Cut trench into stable soil material, at least 2 ft wide and at least 2 ft deep with side slopes 1H: 1V or flatter.

Backfill with clayey soil if available. Compaction requirements: same as those for embankment. The trench should be de-watered during the backfilling and compaction operations.

Principal Spillway

Use only approved watertight assemblies as shown in the plans for all pipe connections. Rod and lug connector bands with gaskets are recommended for corrugated pipe. Do not use dimple (universal) connector bands. Connection between pipe and anti-seep collar must be watertight.

Place barrel and riser on firm, even foundation. Install anti-seep collar(s) slightly downstream of dam centerline.

Place moist, clayey, workable soil around pipe and anti-seep collars. Do not use pervious material such as sand, gravel, or silt. Compact 4-inch layers of soil, by hand, under and around pipe and collars to at least the density of foundation soil. Avoid raising pipe from firm contact with foundation while compacting material under pipe haunches.

Cover pipe to a depth of 2 feet minimum of hand-compacted backfill before crossing it with construction equipment.

Anchor riser in place with concrete to prevent flotation. Embed riser at least 6 inches into concrete.

Install trash guard with bars spaced 2-3 inches apart.

Install riprap apron at pipe outlet, width 5 ft minimum. Extend apron to stable grade (length 10 ft minimum). Use well-graded stone with "d50" of 9 inches minimum.

Embankment

Scarify base of dam before placing fill.

Fill material should be placed in 6- to 8-inch continuous layers over the entire length of the fill and compacted. Save the least permeable soil for center portion of dam. Place the most permeable soil in downstream toe.

Compaction may be obtained by routing the hauling equipment over the fill so that the entire surface of each layer of the fill is traversed by at least one wheel or tread track of the equipment. If compaction is obtained with hauling equipment, an elevation 10 percent higher than the design height is required to allow for settlement. If compactors are used for compaction, the overbuild may be reduced to not less than 5 percent.

Fill material must contain sufficient moisture that it can be formed by hand into a ball without crumbling. If water can be squeezed out of the ball, it is too wet for proper compaction.

Construct dam to lines and grades shown in plan. Side slopes must be 2.5:1 or flatter.

Compact fill material in 6- to 8-inch continuous layers over length of dam. Compaction may be obtained by routing construction equipment over fill so that the entire surface of each layer is traversed by at least one wheel of compacting equipment. Protect spillway barrel with 2 ft of hand-compacted fill before traversing with equipment

Construct embankment 10% higher than design height to allow for settlement.

Emergency Spillway

Cut emergency spillway in undisturbed soil to lines and grade shown in the approved plan. Side slopes must be 3:1 or flatter.

Control section must be level and straight, 20 ft long minimum. Exit section must be straight.

Vegetate spillway as soon as grading is complete, following all requirements in vegetation plan. Anchor mulch in spillway with netting.

Install paving material to finished grade if spillway is not to be vegetated.

Cleanout

Place reference stake at sediment cleanout elevation (50% of design volume).

Erosion Control

Minimize the area disturbed and time of exposure.

Excavate the outlet apron area first, to use as a sediment trap during construction of dam.

Use temporary diversions to prevent surface water from running onto disturbed areas.

Construct embankment before clearing the sediment pool.

Stabilize all disturbed areas except lower one-half of sediment basin immediately after construction.

Safety

Sediment basins should be installed only on sites where failure of the structure would not result in loss of life, damage to homes or buildings, or interruption of use or service of public roads or utilities.

Sediment basins are attractive to children and can be very dangerous.

Keep sediment pool dewatered between storms.

Construct side slopes 2:1 or flatter in pool area.

Fence area if trespassing is likely. Post signs warning the public of hazards of soft sediment and floodwater.

Follow all state and local requirements.

Common Trouble Points

Piping failure along conduit

Due to lack of proper compaction, omission of anti-seep collar, or leaking pipe joints.

Erosion of spillway or embankment slopes
Due to inadequate vegetation or improper grading and sloping.
Slumping and/or settling of embankment
Due to inadequate compaction and/or use of poor-quality fill material.
Slumping failure
Due to steep side slopes.
Erosion and caving below pipe
Due to inadequate outlet protection.
Basin not located properly for access
Makes maintenance difficult and costly.
Sediment not properly removed
Leaves inadequate storage capacity.
Lack of anti-flotation pipe
Damage from uplift.
Lack of trash rack
Barrel and riser blocked with debris.
Elevations of principal spillway and emergency spillway too high relative to top of dam
Potential failure from overtopping.

Maintenance

Sediment basins should be readily accessible for maintenance and sediment removal. The sediment basin should remain in operation and be properly maintained until the site area is permanently stabilized by vegetation and/or when permanent structures are in place.

Inspect sediment basins after each significant rainfall.

Remove and properly dispose of sediment when it accumulates to one-half design volume (level marked by reference stake). The effectiveness of a sediment pond is based less on its size than on regular sediment removal.

Check embankment, emergency spillway, and outlet for erosion damage.

Check embankment for: settlement, seepage, or slumping along the toe or around pipe. Look for signs of piping. Repair immediately. Remove trash and other debris from principal spillway, emergency spillway, and pool area.

Clean or replace gravel when sediment pool does not drain properly.

Remove basin after drainage area has been permanently stabilized, inspected, and approved. Before removing dam, drain water and remove sediment; place waste material in designated disposal areas. Smooth site to blend with surrounding area and stabilize.

References

Massachusetts Department of Environmental Protection, Office of Watershed Management, Nonpoint Source Program, ***Massachusetts Nonpoint Source Management Manual***, Boston, Massachusetts, June, 1993.

Minnick, E. L., and H. T. Marshall, ***Stormwater Management and Erosion Control for Urban and Developing Areas in New Hampshire***, Rockingham County Conservation District, August 1992.

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Washington State Department of Ecology, ***Stormwater Management Manual for the Puget Sound Basin***, Olympia, WA, February, 1992.

Sediment Fence

A temporary sediment barrier consisting of a filter fabric stretched across and attached to supporting posts and entrenched. The sediment fence is constructed of stakes and synthetic filter fabric with a rigid wire fence backing where necessary for support.

Sediment fence can be purchased with pockets presewn to accept use of steel fence posts.

Purpose

A sediment fence intercepts and detains small amounts of sediment from disturbed areas during construction operations and reduces runoff velocity down a slope.

Sediment fences may also be used to catch wind-blown sand and to create an anchor for sand dune creation.

Where Practice Applies

- Below small disturbed areas of less than ¼ acre per 100 feet of fence, where runoff may occur in the form of sheet and rill erosion.
- Where there is no concentration of water in a channel or other drainageway above the fence, and drainage area is usually not more than 1- ½ acres.
- Where runoff can be stored behind the sediment fence without

damaging the fence, or the submerged area behind the fence.

- Where erosion would occur only in the form of sheet erosion.
- Do not install sediment fences across streams, ditches, or waterways.

Advantages

- Removes sediments and prevents downstream damage from sediment deposits
- Reduces the speed of runoff flow
- Minimal clearing and grubbing required for installation
- Sediment fences trap a much higher percentage of suspended sediments than straw bales.

Disadvantages/Problems

Sediment fences are not practical where large flows of water are involved. Their use is recommended only for small drainage areas, and flow rates of less than 0.5 cfs.

Flow should not be concentrated; it should be spread out over many linear feet of sediment fence.

Problems may arise from incorrect selection of filter fabric or from improper installation.

Sediment fences are not an adequate method of runoff control for anything deeper than sheet or overland flow.

Planning Considerations

Sediment fences should be located where they will trap sediment; that is, where there will be contributing runoff. A sediment fence, located along the top of a ridge serves no useful purpose, except as it may be used to mark limits of a construction area. A sediment fence located at the upper end of a drainage area performs no sediment-collecting function.

Sediment fences are preferable to straw barriers in many cases. While the failure rate is lower than that of straw barriers there are, however, many cases in which sediment fences have been improperly installed.

Sediment fences have a low permeability to enhance sediment trapping. This will create ponding behind the fence, so they should not be located where ponding will cause property damage or a safety hazard.

The sedimentation pool behind the fence is very effective and may reduce the need for sediment basins and traps.

Sediment fences may be designed to store all the runoff from the design storm or located to allow bypass flow when the temporary sediment pool reaches a predetermined level.

The drainage area must be restricted and the fence located so that water depth does not exceed 1.5 feet at any point.

The expected life of a sediment fence is generally six months.

To use sediment fences effectively, provide access to the locations where sediment accumulates and provide reinforced, stabilized outlets for emergency overflow.

Sediment fence is most effective when used in conjunction with other practices such as perimeter dikes or diversions.

Allow for safe bypass of storm flow to prevent overtopping failure of fence.

Do not install sediment fence across intermittent or permanent streams, channels, or any location where concentrated flow is anticipated.

It is not necessary to use straw or hay bales together with a sediment fence.

Design Recommendations

Depth of impounded water should not exceed 1.5 feet at any point along the fence.

Drainage area

Limited to ¼ acre per 100 ft of fence, and no more than 1.5 acres in total; or in combination with a sediment basin on a larger site. Area is further restricted by slope steepness as shown in the following table.

	Maximum Slope
Land Slope (%)	Distance Above Fence (feet)
2	250
5	180
10	100
20	50
30	30

Location

Locate the fence at least 10 feet from the toe of steep slopes to provide sediment storage and access for cleanout.

The fence line should be nearly level through most of its length to impound a broad, temporary pool. The last 10 to 20 feet at each end of the fence should be swung slightly uphill (approximately 0.5 feet in elevation) to provide stroage capacity.

Stabilized outlets are required for bypass flow, unless the fence is designed to retain all runoff from the 10-year storm.

The fence line may run slightly off level (grade less than 1%) if it terminates in a level section with a stabilized outlet, diversion, basin, or sediment trap. There must be no gullying along the fence or at the ends. A sediment fence should not be used as a diversion.

Materials and Use

Filter Fabric

The filter fabric used in a sediment fence must have sufficient strength to withstand various stress conditions. It also must have the ability to allow passage of water while retaining soil particles. Filter fabric for a sediment fence is available commercially.

Support posts

Four-inch diameter pine, 1.33 lb./linear ft. steel, or sound quality hardwood with a minimum cross sectional area of 3.0 square inches. Steel posts should have projections for fastening fabric.

Drive posts securely, at least 16 inches into the ground, on the downslope side of the trench. Space posts a maximum of 8 feet if fence is supported by wire, 6 feet if extra-strength fabric is used without support wire. Adjust spacing to place posts at low points along the fenceline.

Support wire

Wire fence (14 gauge with 6-inch mesh) is required to support standard-strength fabric.

Reinforced, stabilized outlets

Any outlet where storm flow bypass occurs must be stabilized against erosion.

Set outlet elevation so that water depth cannot exceed 1.5 feet at the lowest point along the fenceline.

Set fabric height at 1 foot maximum between support posts spaced no more than 4 feet apart. Install a horizontal brace between the support posts to serve as an overflow weir and to support top of fabric. Provide a riprap splash pad a minimum 5 feet wide, 1 foot deep, and 5 feet long on level grade. The finished surface of the riprap should blend with surrounding area, allowing no overfall. The area around the pad must be stable.

Construction Recommendations

Dig a trench approximately 8 inches deep and 4 inches wide, or a V-trench; along the line of the fence, upslope side.

Fasten support wire fence securely to the upslope side of fence posts with wire ties or staples. Wire should extend 6 inches into the trench.

Attach continuous length of fabric to upslope side of fence posts. Avoid joints, particularly at low points in the fence line. Where joints are necessary, fasten fabric securely to support posts and overlap to the next post.

Place the bottom one foot of fabric in the trench. Backfill with compacted earth or gravel.

Filter cloth shall be fastened securely to the woven wire fence with ties spaced every 24 inches at the top, mid-section, and bottom.

To reduce maintenance, a shallow sediment storage area may be excavated on the upslope side of fence where sedimentation is expected.

Provide good access to deposition areas for cleanout and maintenance.

Sediment fences should be removed when they have served their useful purpose, but not before the upslope area has been permanently stabilized. Retained sediment must be removed and properly disposed of, or mulched and seeded.

Common Trouble Points

Fence sags or collapses:

- Drainage area too large,
- Too much sediment accumulation allowed before cleanout,
- Approach too steep, or
- Fence not adequately supported.

Fence fails from undercutting:

- Bottom of fence not buried at least 8 inches at all points,
- Trench not backfilled with compacted earth or gravel,
- Fence installed on excessive slope, or
- Fence located across drainage way.

Fence is overtopped:

- Storage capacity inadequate, or
- No provision made for safe bypass of storm flow, or
- Fence located across drainage way.

Erosion occurs around end of fence:

- Fence terminates at elevation below the top of the temporary pool.
- Fence terminates at unstabilized area, or
- Fence located on excessive slope.

Maintenance

A sediment fence requires a great deal of maintenance. Silt fences should be inspected immediately after each rainfall and at least daily during prolonged rainfall. Repair as necessary.

Remove sediment deposits promptly to provide adequate storage volume for the next rain and to reduce pressure on fence. Take care to avoid undermining fence during cleanout.

If the fabric tears, decomposes, or in any way becomes ineffective, replace it immediately.

Replace burlap used in sediment fences after no more than 60 days.

Remove all fencing materials after the contributing drainage area has been properly stabilized. Sediment deposits remaining after the fabric has been removed should be graded to conform with the existing topography and vegetated.

References

Massachusetts Department of Environmental Protection, Office of Watershed Management, Nonpoint Source Program, Massachusetts ***Nonpoint Source Management Manual***, Boston, Massachusetts, June, 1993.

Minnick, E. L., and H. T. Marshall, S***tormwater Management and Erosion Control for Urban and Developing Areas in New Hampshire***, Rockingham County Conservation District, August 1992.

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Washington State Department of Ecology, ***Stormwater Management Manual for the Puget Sound Basin***, Olympia, WA, February, 1992.

Sediment Trap

A sediment trap is formed by excavating a pond or by placing an earthen embankment across a low area or drainage swale. An outlet or spillway is constructed using large stones or aggregate to slow the release of runoff. The trap retains the runoff long enough to allow most of the silt to settle out.

Purpose

A sediment trap intercepts sediment-laden runoff from small disturbed areas and detains it long enough for the majority of the sediment to settle out.

Where Practice Applies

A sediment trap is installed:

- As close to the disturbed area or source of sediment as physically possible;
- Where the drainage area is less than 5 acres; and
- Where runoff from undisturbed areas can be excluded from the structure.

A sediment trap may be used in conjunction with other temporary measures, such as gravel construction entrances, vehicle wash areas, slope drains, diversion dikes and swales, or diversion channels.

Advantages

- Reduced sediment deposits downstream.
- Is inexpensive and simple to install.
- Can simplify the design process by trapping sediment at specific spots onsite.
- Disadvantages/Problems
- Effective only if properly maintained.
- Will not remove very fine silts and clays.
- Serves only limited areas.

Planning Considerations

Temporary sediment traps are usually installed in drainage ways with small watersheds. They may be used at a storm drain inlet or outlet.

Locate sediment trap as near the sediment source as topography allows.

Divert runoff from all undisturbed areas away from sediment trap.

Sediment traps should be installed before any land disturbance takes place in the drainage area.

Design Recommendations

Drainage area - Not more than 5 acres.

Sediment storage - The sediment trap should have a minimum volume based on ½ inch of storage for each acre of drainage area. This volume equates to 1800 cubic feet of storage or 67 cubic yards for each acre of drainage area.

Trap efficiency- Length-to-width ratio should be 2:1 or greater; divert inflow to upper end of basin to avoid short-circuiting flow. Length is defined as the average distance from the inlet to the outlet of the trap.

Structure life - Limited to 2 years.

Embankment - The maximum height of the sediment trap embankment should be 5 feet when measured from the lowest point of natural ground on the downstream side of the embankment. The minimum top width of the embankment should be 5 feet. The side slopes of the embankment should be 2:1, horizontal to vertical, or flatter.

Excavations - When excavation is necessary to obtain the required storage, the side slopes should be no steeper than 2:1, horizontal to vertical, in the excavated portion of the basin.

Outlets - The outlet should be designed so that sediment does not leave the trap and erosion does not take place below the outlet. The outlets must empty onto undisturbed ground, into a water course, stabilized channel or a storm sewer system.

Capacity - 10-yr peak storm.
Stone - Hard, angular, well-graded mixture with "d50" of 9 inches minimum. Inside facing lined with a 1-foot thick layer of ½- to ¾-inch washed aggregate.
Side slopes - Spillway and excavated basin, 2:1 or flatter.
Protection from "piping" - Filter fabric or a cut-off trench is required between the stone spillway outlet section and the compacted embankment.
Spillway depth - 1.5 ft minimum below designed, settled top of embankment. Freeboard - 0.5 foot minimum.
Spillway width

Drainage Area (acres)	Minimum Bottom Width (feet)
1	4.0
2	6.0
3	8.0
4	10.0
5	12.0

Outlet apron - 5-ft long, minimum, on level grade with filter fabric foundation.

Construction Recommendations

Embankment

- Clear, grub, and strip all vegetation and root mat from area of embankment. Use stable mineral soil free of roots, rocks, debris, organic material, and other objectionable material.
- Place embankment fill in 9-inch lifts, maximum. The fill should be compacted by routing construction equipment so that the entire area of the fill is transversed by at least one wheel or tread track of the equipment. Construct side slopes 2:1 or flatter (3:1 recommended for backslope to improve stability of stone spillway).
- Overfill embankment to 6 inches above design elevation to allow for settlement.
- Outlet crest elevations should be at least one foot below the top of the embankment.

Outlet Section

- Excavate trapezoidal stone outlet section from compacted embankment. Allow for thickness of stone side slopes (21 inches minimum).
- Install filter fabric under riprap. Extend fabric up the sides to top of embankment.

A place-specified stone to lines and grades shown on plans, working the smaller stones into the voids to achieve a dense mass. Spillway crest must be level with minimum inside dimension specified in plan. Measure spillway depth from the highest stones in the spillway to the design elevation of dam. Minimum depth is 1.5 foot.

- Keep sides of the stone outlet section at least 21 inches thick through the level section and the downstream face of dam.
- Extend outlet apron below toe of dam on level grade until stable conditions are reached (5 feet minimum). Edges and end of the stone apron section must be flush with surrounding ground. No overfall should exist.
- Cover inside face of stone outlet section with a 1-foot thick layer of ½- to ¾-inch aggregate.

Vegetation

All embankments, earth spillways, and disturbed areas downstream from the structure should be vegetated within 3 days of completion of the construction of the structure. If the structure is not planned for more than one vegetative growing season, the structure may be vegetated using in **Temporary Seeding** recommendations. Basins that will be carried over the winter and into the next vegetative growing season should be vegetated using **Permanent Seeding** recommendations.

Common Trouble Points

Inadequate spillway size

Results in overtopping of dam, poor trap efficiency and possible failure of the structure. Modification of the plan may be required.

Omission of or improper installation of filter fabric

Results in washout under sides or bottom of the stone outlet section (piping).

Low point in embankment caused by inadequate compaction and settling

Results in overtopping and possible failure.

Stone outlet apron does not extend to stable grade

Results in erosion below the dam.

Stone size too small or backslope too steep

Results in stone displacement.

Inadequate vegetative protection

Results in erosion of embankment.

Inadequate storage capacity

Sediment not removed from basin frequently enough.

Contact slope between stone spillway and earth embankment too steep

Piping failure is likely.

Maintenance

The effective life of a sediment trap depends upon adequate maintenance. The trap should be readily accessible for periodic maintenance and sediment removal.

Set a stake at one-half the design depth. This will be the "cleanout level." Remove sediment when it has accumulated to one-half the design depth.

Inspect sediment traps after each significant rainfall event. Repair any erosion and piping holes immediately.

Clean or replace spillway gravel facing if clogged.

Promptly replace any displaced riprap, being careful that no stones in the spillway are above design grade.

Inspect vegetation; reseed and remulch if necessary.

Check spillway depth periodically to ensure minimum of 1.5 ft depth from lowest point of the settled embankment to highest point of spillway crest. Fill any low areas of the embankment to maintain design elevation.

After all sediment-producing areas have been stabilized, inspected, and approved, remove the structure and all unstable sediment. Smooth site to blend with adjoining areas and stabilize in accordance with vegetation plan.

References

Minnick, E. L., and H. T. Marshall, ***Stormwater Management and Erosion Control for Urban and Developing Areas in New Hampshire***, Rockingham County Conservation District, August 1992.

North Carolina Department of Environment, Health, and Natural Resources, ***Erosion and Sediment Control Field Manual***, Raleigh, NC, February 1991.

U.S. Environmental Protection Agency, ***Storm Water Management For Construction Activities***, EPA-832-R- 92-005, Washington, DC, September, 1992.

Washington State Department of Ecology, ***Stormwater Management Manual for the Puget Sound Basin***, Olympia, WA, February, 1992.

Seeding, Permanent

The establishment of perennial vegetative cover on disturbed areas.

Purpose

Permanent seeding of grass and planting trees and shrubs provides stabilization to the soil by holding soil particles in place.

Vegetation reduces sediments and runoff to downstream areas by slowing the velocity of runoff and permitting greater infiltration of the runoff.

Vegetation also filters sediments, helps the soil absorb water, improves wildlife habitats, and enhances the aesthetics of a site.

Where Practice Applies

- Permanent seeding and planting is appropriate for any graded or cleared area where long-lived plant cover is needed to stabilize the soil.
- Areas which will not be brought to final grade for a year or more.
- Some areas where permanent seeding is especially important are filter strips, buffer areas, vegetated swales, steep slopes, and stream banks.
- This practice is effective on areas where soils are unstable because of their texture or structure, high water table, winds, or steep slope.

Advantages

Advantages of seeding over other means of establishing plants include the small initial establishment cost, the wide variety of grasses and legumes available, low labor requirement, and ease of establishment in difficult areas.

Seeding is usually the most economical way to stabilize large areas.

Well established grass and ground covers can give an aesthetically pleasing, finished look to a development.

Once established, the vegetation will serve to prevent erosion and retard the velocity of runoff.

Disadvantages/Problems

Disadvantages which must be dealt with are the potential for erosion during the establishment stage, a need to reseed areas that fail to establish, limited periods during the year suitable for seeding, and a need for water and appropriate climatic conditions during germination. Vegetation and mulch cannot prevent soil slippage and erosion if soil is not inherently stable.

Coarse, high grasses that are not mowed can create a fire hazard in some locales. Very short mowed grass, however, provides less stability and sediment filtering capacity.

Grass planted to the edge of a watercourse may encourage fertilizing and mowing near the water's edge and increase nutrient and pesticide contamination.

Depends initially on climate and weather for success.

May require regular irrigation to establish and maintain.

Planning considerations

Selection of the right plant materials for the site, good seedbed preparation, timing, and conscientious maintenance are important. Whenever possible, native species of plants should be used for landscaping. These plants are already adapted to the locale and survivability should be higher than with "introduced" species.

Native species are also less likely to require irrigation, which can be a large maintenance burden and is neither cost-effective nor ecologically sound.

If non-native plant species are used, they should be tolerant of a large range of growing conditions, as low-maintenance as possible, and not invasive.

Consider the microclimate within the development area. Low areas may be frost pockets and require hardier vegetation since cold air tends to sink and flow towards low spots. South-facing slopes may be more difficult to re-vegetate because they tend to be sunnier and drier.

Divert as much surface water as possible from the area to be planted.

Remove seepage water that would continue to have adverse effects on soil stability or the protecting vegetation. Subsurface drainage or other engineering practices may be needed. In this situation, a permit may be needed from the local Conservation Commission: check ahead of time to avoid construction delays.

Provide protection from equipment, trampling and other destructive agents.

Vegetation cannot be expected to supply an erosion control cover and prevent slippage on a soil that is not stable due to its texture, structure, water movement, or excessive slope.

Seeding Grasses and Legumes

Install needed surface runoff control measures such as gradient terraces, berms, dikes, level spreaders, waterways, and sediment basins prior to seeding or planting.

Seedbed Preparation

If infertile or coarse-textured subsoil will be exposed during land shaping, it is best to stockpile topsoil and respread it over the finished slope at a minimum 2- to 6-inch depth and roll it to provide a firm seedbed. If construction fill operations have left soil exposed with a loose, rough, or irregular surface, smooth with blade and roll.

Loosen the soil to a depth of 3-5 inches with suitable agricultural or construction equipment.

Areas not to receive top soil shall be treated to firm the seedbed after incorporation of the lime and fertilizer so that it is depressed no more than ½ - 1 inch when stepped on with a shoe. Areas to receive topsoil shall not be firmed until after topsoiling and lime and fertilizer is applied and incorporated, at which time it shall be treated to firm the seedbed as described above. This can be done by rolling or cultipacking.

Cool Season Grasses

Cool Season Grasses grow rapidly in the cool weather of spring and fall, and set seed in June and July. Cool season grasses become dormant when summer temperatures persist above 85 degrees and moisture is scarce.

Lime and Fertilizer

Apply lime and fertilizer according to soil test and current Extension Service recommendations. In absence of a soil test, apply lime (a pH of 5.5 - 6.0 is desired) at a rate of 2.5 tons per acre and 10-20-20 analysis fertilizer at a rate of 500 pounds per acre (40 % of N to be in an organic or slow release form). Incorporate lime and fertilizer into the top 2-3 inches of soil.

Seeding Dates

Seeding operations should be performed within one of the following periods:

- April 1 - May 31,
- August 1 - September 10,
- November 1 - December 15 as a dormant seeding (seeding rates shall be increased by 50% for dormant seedings).

Seeding Methods

Seeding should be performed by one of the following methods. Seed should be planted to a depth of ¼ to ½ inches.

- Drill seedings,
- Broadcast and rolled, cultipacked or tracked with a small track piece of construction equipment,
- Hydroseeding, with subsequent tracking.

Mulch

Mulch the seedings with straw applied at the rate of ½ tons per acre. Anchor the mulch with erosion control netting or fabric on sloping areas.

Warm Season Grasses

Warm Season Grasses begin growth slowly in the spring, grow rapidly in the hot summer months and set seed in the fall. Many warm season grasses are sensitive to frost in the fall, and the top growth may die back. Growth begins from the plant base the following spring.

Lime and Fertilizer

Lime to attain a pH of at least 5.5. Apply a 0-10-10 analysis fertilizer at the rate of 600 lbs./acre.
Incorporate both into the top 2-3 inches of soil. (30 lbs. of slow release nitrogen should be applied after emergence of grass in the late spring.)

Seeding Dates

Seeding operations should be performed as an early spring seeding (April 1-May 15) with the use of cold treated seed. A late fall early winter dormant seeding (November 1 - December 15) can also be made, however the seeding rate will need to be increased by 50%.

Seeding Methods

Seeding should be performed by one of the following methods:

- Drill seedings (de-awned or de-bearded seed should be used unless the drill is equipped with special features to accept awned seed).
- Broadcast seeding with subsequent rolling, cultipacking or tracking the seeding with small track construction equipment. Tracking should be oriented up and down the slope.
- Hydroseeding with subsequent tracking. If wood fiber mulch is used, it should be applied as a separate operation after seeding and tracking to assure good seed to soil contact.

Mulch

Mulch the seedings with straw applied at the rate of ½ tons per acre. Anchor the mulch with erosion control netting or fabric on sloping areas.

Seed Mixtures for Permanent Cover

Recommended mixtures for permanent seeding are provided on the following pages. Select plant species which are suited to the site conditions and planned use. Soil moisture conditions, often the major limiting site factor, are usually classified as follows:

Dry - Sands and gravels to sandy loams. No effective moisture supply from seepage or a high water table.

Moist - Well drained to moderately well drained sandy loams, loams, and finer; or coarser textured material with moderate influence on root zone from seepage or a high water table.

Wet - All textures with a water table at or very near the soil surface, or with enduring seepage.

When other factors strongly influence site conditions, the plants selected must also be tolerant of these conditions.

Permanent Seeding Mixtures

Mix	Site	Seed Mixture	Seed, Pounds per: Acre	Seed, Pounds per: 1,000 sf	Remarks
1	Dry	Little Bluestem			* Use Warm Season planting procedure.
		or Broomsedge	10	0.25	* Roadsides
		Tumble Lovegrass*	1	0.10	* Sand and Gravel Stabilization
		Switchgrass	10	0.25	* Clover requires inoculation with nitrogen-fixing bacteria
		Bush Clover*	2	0.10	
		Red Top	1	0.10	* Rates for this mix are for PLS.
2	Dry	Deertongue	15	0.35	* Use Warm Season planting procedures.
		Broomsedge	10	0.25	* Acid sites/Mine spoil
		Bush Clover*	2	0.10	* Clover requires inoculation with nitrogen-fixing bacteria.
		Red Top	1	0.10	*Rates for this mix are for PLS.
3	Dry	Big Bluestem	10	0.25	* Use Warm Season planting procedures.
		Indian Grass	10	0.25	* Eastern Prairie appearance
		Switchgrass	10	0.25	* Sand and Gravel pits.
		Little Bluestem	10	0.25	* Golf Course Wild Areas
		Red Top or	1	0.10	* Sanitary Landfill Cover seeding
		Perennial Ryegrass	10	0.25	* Wildlife Areas *OK to substitute Poverty Dropseed in place of Red Top/Ryegrass. *Rates for this mix are for PLS.
4	Dry	Flat Pea	25	0.60	* Use Cool Season planting procedures
		Red Top or	2	0.10	* Utility Rights-of-Ways (tends to suppress woody growth)
		Perennial Ryegrass	15	0.35	
5	Dry	Little Bluestem	5	0.10	* Use Warm Season planting procedures.
		Switchgrass	10	0.25	* Coastal sites
		Beach Pea*	20	0.45	* Rates for Bluestein and Switchgrass are for PLS.
		Perennial Ryegrass	10	0.25	
6	Dry - Moist	Red Fescue	10	0.25	* Use Cool Season planting procedure.
		Canada Bluegrass	10	0.25	* Provides quick cover but is non-aggressive;
		Perennial Ryegrass	10	0.25	will tend to allow indigenous plant colonization.
		Red Top	1	0.10	* General erosion control on variety of sites, including forest roads, skid trails and landings.
7	Moist-Wet	Switchgrass	10	0.25	* Use Warm Season planting procedure.
		Virginia Wild Rye	5	0.10	* Coastal plain/flood plain
		Big Bluestem	15	0.35	* Rates for Bluestem and Switchgrass are for PLS.
		Red Top	1	0.10	

Permanent Seeding Mixtures

Mix	Site	Seed Mixture	Seed, Pounds per: Acre	Seed, Pounds per: 1,000 sf	Remarks
8	Moist	Creeping Bentgrass	5	0.10	* Use Cool Season planting procedures.
	Wet	Fringed Bromegrass	5	0.10	* Pond Banks
		Fowl Meadowgrass	5	0.10	* Waterways/ditch banks
		Bluejoint Reedgrass or Rice Cutgrass	2	0.10	
		Perennial Ryegrass	10	0.25	
9	Moist	Red Fescue	5	0.10	*Salt Tolerant
	Wet	Creeping Bentgrass	2	0.10	* Fescue and Bentgrass provide low growing appearance, while Switchgrass provides tall cover for wildlife.
		Switchgrass	8	0.20	
		Perennial Ryegrass	10	0.25	
10	Moist	Red Fescue	5	0.10	* Use Cool Season planting procedure.
	Wet	Creeping Bentgrass	5	0.10	* Trefoil requires inoculation with nitrogen fixing bacteria.
		Virginia Wild Rye	8	0.20	
		Wood Reed Grass*	1	0.10	* Suitable for forest access roads, skid trails and other partial shade situations.
		Showy Tick Trefoil*	1	0.10	
11	Moist	Creeping Bentgrass	5	0.10	* Use Cool Season planting procedure.
	Wet	Bluejoint Reed Grass	1	0.10	* Suitable for waterways, pond or ditch banks.
		Virginia Wild Rye	3	0.10	* Trefoil requires inoculation with nitrogen fixing bacteria.
		Fowl Meadow Grass	10	0.25	
		Showy Tick Trefoil*	1	0.10	
		Red Top	1	0.10	
12	Wet	Blue Joint Reed Grass	1	0.10	* Use Cool Season planting procedure.
		Canada Manna Grass	1	0.10	* OK to seed in saturated soil conditions, but not in standing water.
		Rice Cut Grass	1	0.10	
		Creeping Bent Grass	5	0.10	* Suitable as stabilization seeding for created wetland.
		Fowl Meadow Grass	5	0.10	* All species in this mix are native to Massachusetts.
13	Dry - Moist	American Beachgrass	18”	18’ centers	*Vegetative planting with dormant culms, 3-5 culms per planting centers
14	Inter- Tidal	Smooth Cordgrass Saltmeadow Cordgrass	12-18”	12-18” centers	* Vegetative planting with transplants. centers

Notes:
* Species such as Tumble Lovegrass, Fringed Bromegrass, Wood Reedgrass, Bush Clover and Beach Pea, while known to be commercially available from specific seed suppliers, may not always be available from your particular seed suppliers. The local Natural Resources Conservation Service office may be able to help with a source of supply. In the event a particular species listed in a mix can not be obtained, however, it may be possible to substitute another species.
Seed mixtures by courtesy of Natural Resources Conservation Service, Amherst, MA.

(PLS) Pure Live Seed

Warm Season grass seed is sold and planted on the basis of pure live seed. An adjustment is made to the bulk rate of the seed to compensate for inert material and non-viable seed. Percent of pure live seed is calculated by multiplying the percent purity by the percent germination; (% purity) x (% germination) = percent PLS.
For example, if the seeding rate calls for 10 lbs./acre PLS and the seed lot has a purity of 70% and germination of 75%, the PLS factor is:

(.70 x .75) =.53

10 lbs. divided by .53 = approx. 19 lbs.

Therefore, 19 lbs of seed from the particular lot will need to be applied to obtain 10 lbs. of pure live seed.

Special Note

Tall Fescue, Reed Canary Grass, Crownvetch and Birdsfoot Trefoil are no longer recommended for general erosion control use in Massachusetts due to the invasive characteristics of each. If these species are used, it is recommended that the ecosystem of the site be analyzed for the effects species invasiveness may impose. The mixes listed in the above mixtures include either species native to Massachusetts or non-native species that are not perceived to be invasive, as per the Massachusetts Native Plant Advisory Committee.

Wetlands Seed Mixtures

For newly created wetlands, a wetlands specialist should design plantings to provide the best chance of success. Do not use introduced, invasive plants like reed canarygrass (Phalaris arundinacea) or purple loosestrife (Lythrum salicaria). Using plants such as these will cause many more problems than they will solve.

The following grasses all thrive in wetland situations:

- Fresh Water Cordgrass (*Spartina pectinata*)
- Marsh/Creeping Bentgrass (*Agrostis stolonifera, var. Palustric*)
- Broomsedge (*Andropogon virginicus*)
- Fringed Bromegrass (*Bromus ciliatus*)
- Blue Joint Reed Grass (*Calamagrostis cavedensis*)
- Fowl Meadow Grass (*Glyceria striata*)
- Riverbank Wild Rye (*Elymus riparius*)
- Rice Cutgrass (*Leersia oryzoides*)
- Stout Wood Reed (*Cinna arundinacea*)
- Canada Manna Grass (*Glyceria canadensis*)

A sample wetlands seed mix developed by The New England Environmental Wetland Plant Nursery is shown on the following page.

Wetland Seed Mixture

The New England Environmental Wetland Plant Nursery has developed a seed mixture which is specifically designed to be used in wetland replication projects and stormwater detention basins. It is composed of seeds from a variety of indigenous wetland species. Establishing a native wetland plant understory in these areas provides quick erosion control, wildlife food and cover, and helps to reduce the establishment of undesirable invasive species such as Phragmites and purple loosestrife (Lythrum salicaria). The species have been selected to represent varying degrees of drought tolerance, and will establish themselves based upon microtopography and the resulting variation in soil moisture.

Common Name (*Scientific Name*)	% in Mix	Comments
Lurid Sedge (*Carex lurida*)	30	A low ground cover that tolerates mesic sites in addition to saturated areas; prolific seeder in second growing season.
Fowl Meadow Grass (*Glyceria Canadensis*)	25	Prolific seed producer that is a valuable wildlife food source.
Fringed Sedge (*Carex crinita*)	10	A medium to large sedge that tolerates saturated areas; good seed producer.
Joe-Pye Weed (*Eupatoriadelphus maculatus*)	10	Flowering plant that is valuable for wildlife cover. Grows to 4 feet.
Brook Sedge (*Carex spp., Ovales group*)	10	Tolerates a wide range of hydrologic conditions.
Woolgrass (*Scirpus cyperinus*)	5	Tolerates fluctuating hydrology.
Boneset (*Eupatorium perfoliatum*)	5	Flowering Plant that is valuable for wildlife cover. Grows to 3 feet.
Tussock Sedge (*Carex stricta*)	<5	Grows in elevated hummocks on wet sites, may grow rhizomonously on drier sites.
Blue Vervain (*Verbena hastata*)	<5	A native plant that bears attractive, blue flowers.

The recommended application rate is one pound per 5,000 square feet when used as an understory cover. This rate should be increased to one pound per 2,500 square feet for detention basins and other sites which require a very dense cover. For best results, a late fall application is recommended. This mix is not recommended for standing water.

Maintenance

Inspect seeded areas for failure and make necessary repairs and reseed immediately. Conduct or follow-up survey after one year and replace failed plants where necessary.

If vegetative cover is inadequate to prevent rill erosion, overseed and fertilize in accordance with soil test results.

If a stand has less than 40% cover, reevaluate choice of plant materials and quantities of lime and fertilizer. Re-establish the stand following seedbed preparation and seeding recommendations, omitting lime and fertilizer in the absence of soil test results. If the season prevents resowing, mulch or jute netting is an effective temporary cover.

Seeded areas should be fertilized during the second growing season. Lime and fertilize thereafter at periodic intervals, as needed.

References

North Carolina Department of Environment, Health, and Natural Resources, ***Erosion and Sediment Control Field Manual***, Raleigh, NC, February 1991.

Personal communication, Richard J. DeVergilio, USDA, Natural Resources Conservation Service, Amherst, MA.

U.S. Environmental Protection Agency, ***Storm Water Management For Construction Activities***, EPA-832-R- 92-005, Washington, DC, September, 1992.

Washington State Department of Ecology, ***Stormwater Management Manual for the Puget Sound Basin***, Olympia, WA, February, 1992.

Seeding, Temporary

Planting rapid-growing annual grasses, small grains, or legumes to provide initial, temporary cover for erosion control on disturbed areas.

Purpose

To temporarily stabilize areas that will not be brought to final grade for a period of more than 30 working days.
To stabilize disturbed areas before final grading or in a season not suitable for permanent seeding.
Temporary seeding controls runoff and erosion until permanent vegetation or other erosion control measures can be established.
Root systems hold down the soils so that they are less apt to be carried offsite by storm water runoff or wind.
Temporary seeding also reduces the problems associated with mud and dust from bare soil surfaces during construction.

Where Practice Applies

On any cleared, unvegetated, or sparsely vegetated soil surface where vegetative cover is needed for less than one year. Applications of this practice include diversions, dams, temporary sediment basins, temporary road banks, and topsoil stockpiles.

Where permanent structures are to be installed or extensive re-grading of the area will occur prior to the establishment of permanent vegetation.

Areas which will not be subjected to heavy wear by construction traffic.

Areas sloping up to 10% for 100 feet or less, where temporary seeding is the only practice used.

Advantages

This is a relatively inexpensive form of erosion control but should only be used on sites awaiting permanent planting or grading. Those sites should have permanent measures used.

Vegetation will not only prevent erosion from occurring, but will also trap sediment in runoff from other parts of the site.

Temporary seeding offers fairly rapid protection to exposed areas.

Disadvantages/Problems

Temporary seeding is only viable when there is a sufficient window in time for plants to grow and establish cover. It depends heavily on the season and rainfall rate for success.

If sown on subsoil, growth will be poor unless heavily fertilized and limed. Because overfertilization can cause pollution of stormwater runoff, other practices such as mulching alone may be more appropriate. The potential for over-fertilization is an even worse problem in or near aquatic systems.

Once seeded, areas should not be travelled over.

Irrigation may be needed for successful growth. Regular irrigation is not encouraged because of the expense and the potential for erosion in areas that are not regularly inspected.

Planning Considerations

Temporary seedings provide protective cover for less than one year. Areas must be reseeded annual or planted with perennial vegetation.

Temporary seeding is used to protect earthen sediment control practices and to stabilize denuded areas that will not be brought into final grade for several weeks or months. Temporary seeding can provide a nurse crop for permanent vegetation, provide residue for soil protection and seedbed preparation, and help prevent dust production during construction.

Use low-maintenance native species wherever possible.

Planting should be timed to minimize the need for irrigation.

Sheet erosion, caused by the impact of rain on bare soil, is the source of most fine particles in sediment. To reduce this sediment load in runoff, the soil surface itself should be protected. The most efficient and economical means of controlling sheet and rill erosion is to establish vegetative cover. Annual plants which sprout rapidly and survive for only one growing season are suitable for establishing temporary vegetative cover. Temporary seeding is effective when combined with construction phasing so bare areas of the site are minimized at all times.

Temporary seeding may prevent costly maintenance operations on other erosion control systems. For example, sediment basin clean-outs will be reduced if the drainage area of the basin is seeded where grading and construction are not taking place. Perimeter dikes will be more effective if not choked with sediment.

Proper seedbed preparation and the use of quality seed are important in this practice just as in permanent seeding. Failure to carefully follow sound agronomic recommendations will often result in an inadequate stand of vegetation that provides little or no erosion control.

Soil that has been compacted by heavy traffic or machinery may need to be loosened. Successful growth usually requires that the soil be tilled before the seed is applied. Topsoiling is not necessary for temporary seeding; however, it may improve the chances of establishing temporary vegetation in an area.

Planting Procedures

Time of Planting

Planting should preferably be done between April 1 and June 30, and September 1 through September 30. If planting is done in the months of July and August, irrigation may be required. If planting is done between October 1 and March 31, mulching should be applied immediately after planting. If seeding is done during the summer months, irrigation of some sort will probably be necessary.

Site Preparation

Before seeding, install needed surface runoff control measures such as gradient terraces, interceptor dike/swales, level spreaders, and sediment basins.

Seedbed Preparation

The seedbed should be firm with a fairly fine surface.

Perform all cultural operations across or at right angles to the slope. See **Topsoiling** and **Surface Roughening** for more information on seedbed preparation. A minimum of 2 to 4 inches of tilled topsoil is required.

Liming and Fertilization

Apply uniformly 2 tons of ground limestone per acre (100 lbs. per 1,000 Sq. Ft.) or according to soil test.

Apply uniformly 10-10-10 analysis fertilizer at the rate of 400 lbs. per acre (14 lbs. per 1,000 Sq. Ft.) or as indicated by soil test. Forty percent of the nitrogen should be in organic form.

Work in lime and fertilizer to a depth of 4 inches using any suitable equipment.

Seedings for Temporary Cover

Species	*Seeding Rates lbs/sq.ft.* 1,000 Sq.Ft.	Acre	*Recommended* Seeding Dates
Annual Ryegrass	1	40	April 1 to June 1 Aug. 15 to Sept. 15
Foxtail Millet	0.7	30	May 1 to June 30
Oats	2	80	April 1 to July 1 August 15 to Sept. 15
Winter Rye	3	120	Aug. 15 to Oct. 15

“Hydro-seeding” applications with appropriate seed-mulch-fertilizer mixtures may also be used.

Seeding

Select adapted species from the accompanying table.

Apply seed uniformly according to the rate indicated in the table by broadcasting, drilling or hydraulic application.

Cover seeds with suitable equipment as follows:

- Rye grass ¼ inch
- Millet ½ to ¾ inch
- Oats 1 to 1-1/2 inches
- Winter rye 1 to 1-1/2 inches.

Mulch

Use an effective mulch, such as clean grain straw; tacked and/or tied down with netting to protect seedbed and encourage plant growth.

Common Trouble Points

Lime and fertilizer not incorporated to at least 4 inches

May be lost to runoff or remain concentrated near the surface where they may inhibit germination.

Mulch rate inadequate or straw mulch not tacked down

Results in poor germination or failure, and erosion damage. Repair damaged areas, reseed and mulch.

Annual ryegrass used for temporary seeding
Ryegrass reseeds itself and makes it difficult to establish a good cover of permanent vegetation.
Seed not broadcast evenly or rate too low
Results in patchy growth and erosion.

Maintenance

Inspect within 6 weeks of planting to see if stands are adequate. Check for damage after heavy rains. Stands should be uniform and dense. Fertilize, reseed, and mulch damaged and sparse areas immediately. Tack or tie down mulch as necessary.

Seeds should be supplied with adequate moisture. Furnish water as needed, especially in abnormally hot or dry weather or on adverse sites. Water application rates should be controlled to prevent runoff.

References

Massachusetts Department of Environmental Protection, Office of Watershed Management, Nonpoint Source Program, Massachusetts ***Nonpoint Source Management Manual,*** Boston, Massachusetts, June, 1993.

North Carolina Department of Environment, Health, and Natural Resources, ***Erosion and Sediment Control Field Manual***, Raleigh, NC, February 1991.

U.S. Environmental Protection Agency, ***Storm Water Management For Construction Activities***, EPA-832-R- 92-005, Washington, DC, September, 1992.

Washington State Department of Ecology, ***Stormwater Management Manual for the Puget Sound Basin***, Olympia, WA, February, 1992.

Silt Curtain

A temporary sediment barrier installed parallel to the bank of a stream or lake. Used to contain the sediment produced by construction operations on the bank of a stream or lake and allow for its removal.

Where Practice Applies

The silt curtain is used along the banks of streams or lakes where sediment could pollute or degrade the stream or lake.

Planning Considerations

A silt curtain is useful where construction is on the bank of a stream or lake and coarse sediment is a major concern. A silt curtain will not keep the water from being muddy during construction operations, but it will contain the coarse sediment to the construction area. The curtain should obstruct the flow as little as possible to reduce the chance of failure.

Installation Recommendations

The silt curtain should be a filter fabric recommended by the manufacturer for use as a silt curtain. Both ends of the silt curtain should be tied into the bank. The silt curtain should be placed as close as possible to the bank, allowing room for construction operations inside the protected area. In a flowing stream, remove trapped sediment before removing the silt curtain.

The curtain should be anchored to the bottom so sediment cannot go beneath the curtain. It should extend above normal water level. It can be supported by either stakes or floats of adequate strength.

Maintenance

Accumulated sediment must be removed periodically. The curtain must be inspected often and after each storm. Any damage must be immediately repaired.

References

Connecticut Council on Soil and Water Conservation, ***Connecticut Guidelines for Soil Erosion and Sediment Control***, Hartford, CT, January, 1985.

Slope Drain, Temporary

A pipe extending from the top to the bottom of a cut or fill slope and discharging into a stabilized water course or a sediment trapping device or onto a stabilization area. Used to carry concentrated runoff down steep slopes without causing gullies, channel erosion, or saturation of slide-prone soils until permanent water disposal measures can be installed.

Where Practice Applies

This practice applies to construction areas where storm water runoff above a cut or fill will cause erosion if allowed to flow over the slope.

Advantages

Slope drains provide a potentially effective method of conveying water safely down steep slopes.

Disadvantages/Problems

Care must be taken to correctly site drains and not underdesign them. Also, when clearing takes place prior to installing these drains, care must be taken to revegetate the entire easement area, otherwise erosion tends to occur beneath the pipeline, resulting in gully formation.

Planning Considerations

Temporary slope drains are generally used in conjunction with diversions to convey runoff down a slope until permanent water disposal measures can be installed.

There is often a significant lag between the time a cut or fill slope is completed and the time a permanent drainage system can be installed. During this period, the slope is particularly vulnerable to erosion. This situation also occurs on slope construction which is temporarily delayed before final grade is reached.

When used in conjunction with diversion dikes, temporary slope drains can be used to convey stormwater from the entire drainage area above a slope to the base of the slope without erosion.

Slope drains must extend downslope to stable outlets, or special outlet protection must be provided.

It is very important that these temporary structures be sized, installed, and maintained properly since their failure will often result in severe gully erosion. The entrance section must be securely entrenched, all connections must be watertight, and the conduit must be staked securely.

Temporary slope drains should be replaced with more permanent structures as soon as construction activities permit.

Design Recommendations

Capacity

Sufficient to handle a 10-year peak flow. Permanent pipe slope drains should be sized for the 25-year peak flow.

Drainage Area

The maximum drainage area recommended per pipe is ten acres. For larger areas, a rock-lined channel or more than one pipe should be installed.

Material

Strong, flexible pipe such as heavy duty, non-perforated, corrugated plastic.

Pipe size

Based on drainage area:

Maximum Drainage Area Per Pipe (Acres)	Minimum Pipe Diameter (Inches)
0.5	12
0.75	15
1.0	18
>1.0	Individually designed

Entrance

The entrance should consist of a standard flared-end section with a minimum 6-inch metal toe plate to prevent runoff from undercutting the pipe inlet. The slope of the entrance should be at least 3 percent.
Connection to diversion ridge at top of slope: compacted fill over pipe with minimum dimensions 1.5-foot depth, 4-foot top width, and 0.5 foot higher than diversion ridge.
The soil around and under the pipe and entrance section should be thoroughly compacted to prevent undercutting.
The flared inlet section shall be securely connected to the slope drain and have watertight connecting bands.
Slope drain sections shall be securely fastened together and have gasketed watertight fittings, and be securely anchored into the soil.

Interceptor dikes

Interceptor dikes should be used as needed to direct runoff into a slope drain. The height of the dike should be at least 1 foot higher at all points than the top of the inlet pipe.

Outlet

The area below the outlet must be stabilized with a riprap apron.
If the pipe slope drain is conveying sediment-laden water, direct all flows into the sediment trapping facility.

Common Trouble Points

Washout along the pipe due to seepage and piping
Inadequate compaction, insufficient fill, or installation too close to edge of slope.
Overtopping of diversion caused by undersized or blocked pipe
Drainage area may be too large.
Overtopping of diversion caused by improper grade of channel and ridge
Maintain positive grade.
Overtopping due to poor entrance conditions and trash build up at pipe inlet
Deepen and widen channel at pipe entrance; inspect and clear inlet frequently.

Erosion at outlet
Pipe not extended to stable grade or outlet stabilization structure needed.
Displacement or separation of pipe
Tie pipe down and secure joints.
CAUTION!!
Do not divert more water to the slope drain than it was designed to carry.

Maintenance

Failure of a temporary slope drain can cause severe erosion damage. This practice requires intensive maintenance. Inspect slope drains and supporting diversions once a week and after every rainfall event.

Check inlet for sediment or trash accumulation. Clear inlet and restore proper entrance condition. The inlet should be free of undercutting, and no water should be going around the point of entry. If there are problems, the headwall should be reinforced with compacted earth or sand bags.

Check fill over pipe for settlement, cracking, or piping holes. Repair immediately.

Check for seepage holes at point where pipe emerges from dike. Repair immediately.

Check conduit for evidence of leaks or inadequate lateral support. Repair immediately.

Check outlet for erosion or sedimentation. Clean, repair, or extend as needed.

When slopes have been stabilized, inspected, and approved, remove temporary diversions and slope drains and stabilize all disturbed areas.

References

Massachusetts Department of Environmental Protection, Office of Watershed Management, Nonpoint Source Program, ***Massachusetts Nonpoint Source Management Manual,*** Boston, Massachusetts, June, 1993.

North Carolina Department of Environment, Health, and Natural Resources, ***Erosion and Sediment Control Field Manual***, Raleigh, NC, February 1991.

Washington State Department of Ecology, ***Stormwater Management Manual for the Puget Sound Basin***, Olympia, WA, February, 1992.

Sodding

Stabilizing fine-graded disturbed areas by establishing permanent grass stands with sod. To provide immediate erosion protection or to stabilize drainageways where concentrated overland flow will occur.

Where Practice Applies

- Disturbed areas which require immediate vegetative cover.
- Waterways carrying intermittent flow: where immediate stabilization or aesthetics are factors; where velocities will not exceed that specified for a grass lining; and other locations which are particularly suited to stabilization with sod.
- Disturbed areas requiring immediate and permanent vegetative cover. Locations best suited to stabilization with sod are:
- Areas around drop inlets, when the drainage area has been stabilized.
- Steep critical areas.
- If mowing is required, do not use grass sod on slopes steeper than 3: 1. (Use minimum maintenance ground covers.)

Advantages

- Sod gives an immediate vegetative cover, which is both effective in checking erosion and is aesthetically pleasing.
- Provides more stabilizing protection than initial seeding through dense cover formed by sod.
- Produces lower weed growth than seeded vegetation.
- Can be used for site activities within a shorter time than can seeded vegetation.
- Can be placed at any time of the year as long as moisture conditions in the soil are favorable and the ground is not frozen.

Disadvantages/Problems

- Sod is expensive.
- Sod is heavy and handling costs are high.
- Good quality sod, free from weed species, may be difficult to obtain.
- If laid in an unfavorable season, midsummer irrigation may be required.
- Grass species in the sod may not be suitable for site conditions.
- If not anchored or drained properly, sod will “roll up” in grassed waterways.

Planning Considerations

Sod requires careful handling and is sensitive to transport and storage conditions. Soil preparation, installation, and proper maintenance are as important with sod as with seed.

Choosing the appropriate type of sod for site conditions and intended use is of the utmost importance.

Installation

Sod should be free of weeds and be of uniform thickness (approximately 1 inch) and should have a dense root mat for mechanical strength. Sodding is a very expensive method of establishing a grass-type cover but it has the benefit of giving “instant” protection for critical areas. This value may be well worth the higher expense.

Site Preparation

Rake or harrow to achieve a smooth, final grade. Roll or cultipack to create a smooth, firm surface on which to lay the sod. Do not install on compacted clay or pesticide-treated soil. Apply topsoil if needed.

Lime and Fertilizer

Lime according to soil test to pH 6.5, or in the absence of a soil test, apply lime at the rate of 2 to 3 tons of ground limestone per acre (10-15 lbs. per 100 sq. feet).

Fertilize according to soil test or at the rate of 500-1,000 lbs. per acre (1 ¼ to 2 ½ pounds per 100 sq. feet) of 10-5-5 or similar fertilizer. Fertilizer with 40% or more of the nitrogen in organic form is preferred.

Work the lime and fertilizer into the soil 1 or 2 inches deep, and smooth.

Sod

Select high-quality, healthy, vigorous certified-class sod which is at least one year old but not older than three years. It should be a variety that is well-adapted to the region and expected level of maintenance. Common sod types include: Kentucky bluegrass blends, Kentucky bluegrass/Fine fescue mixes and Tall fescue/Kentucky bluegrass mixture.

Sod should be machine cut to a uniform thickness of ¾ inch, plus or minus ¼ inch, at the time of cutting. Measurement of thickness should exclude top growth or thatch.

Standard size sections of sod should be strong enough to support their own weight and retain their size and shape when suspended vertically with a firm grasp of the upper 10% of the section.

Individual pieces of sod should be cut to suppliers width and length. Maximum allowable deviation from the standard widths and lengths should be 5 percent. Broken pads or torn or uneven ends will not be accepted.

If sod is not purchased and local sod is used, cut the sod in strips 12 to 24 inches wide, 6 to 10 feet long, and approximately 1- ¼ inches thick. Roll with roots out to facilitate handling.

Sod should not be harvested or transplanted when the moisture content (excessively wet or dry) may adversely affect its survival.

Sod should be harvested, delivered, and installed within a period of 36 hours. Store rolls of sod in shade during installation. Sod not transplanted within this period should be inspected and approved prior to its installation.

Sod labels should be made available to the job foreman or inspector.

Sod Placement

Rake soil surface to break crust just before laying sod. During periods of high temperature, lightly irrigate the soil immediately prior to placement. Do not install on hot, dry soil, compacted clay, frozen soil, gravel, or soil that has been treated with pesticides.

Sod strips should be laid on the contour, never up and down the slope, starting at the bottom of the slope and working up. Install strips of sod with their longest dimension perpendicular to the slope, and stagger in a brick-like pattern with snug even joints. Do not stretch or overlap. All joints should be butted tightly in order to prevent voids which would cause drying of the roots. Also, open spaces invite erosion.

On slopes greater than 3 to 1, secure sod to surface soil with wood pegs, wire staples, or split shingles (8 to 10 inches long by ¾ inch wide). The use of ladders will facilitate work on steep slopes, and prevent damage to the sod.

Wedge strips securely into place. Square the ends of each strip to provide for a close tight bond. Stagger joints at least 12 inches.

Match angled ends correctly to prevent voids. Use a knife or mason's trowel to trim and fit irregularly shaped areas.

Trim all areas where water enters or leaves the sodded area so that a smooth, flush joint is secured.

Roll or tamp sod immediately following placement to insure solid contact of root mat and soil surface.

Immediately following installation, sod should be watered until moisture penetrates the soil layer beneath sod to a depth of 4 inches. Maintain optimum moisture for at least two weeks.

When sodding is carried out in alternating strips, or other patterns the areas between the sod should be seeded as soon after the sodding as possible.

Surface water cannot always be diverted from flowing over the face of the slope, but a capping strip of heavy jute or plastic netting, properly secured, along the crown of the slope and edges will provide extra protection against lifting and undercutting of sod. The same technique can be used to anchor sod in water-carrying channels and other critical areas. Wire staples must be used to anchor netting in channel work.

Sodded Waterways

Sod provides quicker protection than seeding and may reduce the risk of early washout.

When installing sod in waterways, use the type of sod specified in the channel design.

Lay sod strips perpendicular to the direction of waterflow and stagger in a brick-like pattern. Staple firmly at the corners and middle of each strip. Jute or plastic netting may be pegged over the sod for further protection against washout during establishment.

Common Trouble Points

Sod laid on poorly prepared soil or unsuitable surface.
Grass dies because it is unable to root.
Sod not adequately irrigated after installation.
May cause root dieback; grass does not root rapidly and is subject to drying out.
Sod not anchored properly.
May be loosened by runoff.

Maintenance

Keep sod moist until it is fully rooted.
Inspect sodded areas regularly, especially after large storm events. Re-tack, re-sod, or re-seed as necessary.
Mow to a height of 2-3 inches after sod is well-rooted. Do not remove more than one-third of the shoot in any mowing.
Permanent, fine turf areas require yearly maintenance fertilization. Fertilize warm-season grass in late spring to early summer, cool-season grass in late winter and again in early fall.

References

Massachusetts Department of Environmental Protection, Office of Watershed Management, Nonpoint Source Program, Massachusetts ***Nonpoint Source Management Manual***, Boston, Massachusetts, June, 1993.

North Carolina Department of Environment, Health, and Natural Resources, ***Erosion and Sediment Control Field Manual,*** Raleigh, NC, February 1991.

U.S. Environmental Protection Agency, ***Storm Water Management For Construction Activities***, EPA-832-R- 92-005, Washington, DC, September, 1992.

Straw or Hay Bale Barrier

A temporary sediment barrier consisting of a row of entrenched and anchored straw bales. Used to intercept and detain small amounts of sediment from disturbed areas of limited extent to prevent sediment from leaving the site. Decreases the velocity of sheet flows and low-to-moderate level channel flows.

Where Practice Applies

- Downslope from disturbed areas subject to sheet and rill erosion.
- In minor swales where the maximum contributing drainage area is not more than one acre.
- Where effectiveness is required for less than 3 months.

Advantages

When properly used, straw bale barriers are an inexpensive method of sediment control.

Disadvantages/Problems

Straw bale barriers are easy to misuse. They can become contributors to a sediment problem instead of a solution unless properly located and maintained.

It is difficult to tell if bales are securely seated and snug against each other.

Planning Considerations

Straw or hay bale barriers are used similarly to sediment fence barriers; specifically where the area below the barrier is undisturbed and vegetated. Bale barriers require more maintenance than silt fence barriers and permeability through the bales is slower than sediment fence.

Bales should be located where they will trap sediment; that is, where there will be contributing runoff. Bales located along the top of a ridge serve no useful purpose, except to mark limits of a construction area. Straw or hay bales located at the upper end of a drainage area perform no sediment-collecting function.

Installation

Maximum recommended slope lengths upslope from straw or hay bale barriers are as follows:

Percent Slope	Maximum slope length, feet
1	180
4	100
9	60
14	40
18	30
30	20

(Based on providing storage for 1.0 inch of runoff.)

Bales should be placed in a single row, lengthwise on the contour, with ends of adjacent bales tightly abutting one another.

All bales should be either wire-bound or string-tied. Straw bales should be installed so that bindings are oriented around the sides rather than along the tops and bottoms of the bales in order to prevent deterioration of the bindings.

The barrier should be entrenched and backfilled. A trench should be excavated the width of a bale and the length of the proposed barrier to a minimum depth of 4 inches. The trench must be deep enough to remove all grass and other material which might allow underflow. After the bales are staked and chinked (filled by wedging), the excavated soil should be backfilled against the barrier. Backfill soil should conform to the ground level on the downhill side and should be built up to 4 inches against the uphill side of the barrier.

Each bale should be securely anchored by at least 2 stakes or re-bars driven through the bale. The first stake in each bale should be driven toward the previously laid bale to force the bales together. Stakes or re-bars should be driven deep enough into the ground to securely anchor the bales. For safety reasons, stakes should not extend above the bales but should be driven in flush with the top of the bale.

The gaps between the bales should be chinked (filled by wedging) with straw to prevent water from escaping between the bales. Loose straw scattered over the area immediately uphill from a straw bale barrier tends to increase barrier efficiency. Wedging must be done carefully in order not to separate the bales.

Straw bale barriers should be removed when they have served their usefulness, but not before the upslope areas have been permanently stabilized.

When used in a swale, the barrier should be extended to such a length that the bottoms of the end bales are higher in elevation than the top of the lowest middle bale to assure that sediment-laden runoff will flow either through or over the barrier but not around it.

Common Trouble Points

Improper use

Straw bale barriers have been used in streams and drainageways where high water velocities and volumes have destroyed or impaired their effectiveness.

Improper placement and installation

Staking the bales directly to the ground with no soil seal or entrenchment allows undercutting and end flow. This has resulted in additions to, rather than removal of, sediment from runoff waters.

Inadequate maintenance

Trapping efficiencies of carefully installed straw bale barriers on one project dropped from 57 percent to 16 percent in one month due to lack of maintenance.

Maintenance

Straw bale barriers should be inspected immediately after each runoff-producing rainfall and at least daily during prolonged rainfall.

Close attention should be paid to the repair of damaged bales, undercutting beneath bales, and flow around the ends of the bales.

Necessary repairs to barriers or replacement of bales should be accomplished promptly.

Sediment deposits should be checked after each runoff-producing rainfall. They must be removed when the level of deposition reaches approximately one-half the height of the barrier.

Any sediment deposits remaining in place after the straw bale barrier is no longer required should be dressed to conform to the existing grade, prepared and seeded.

References

Minnick, E. L., and H. T. Marshall, ***Stormwater Management and Erosion Control for Urban and Developing Areas in New Hampshire***, Rockingham County Conservation District, August 1992.

Washington State Department of Ecology, ***Stormwater Management Manual for the Puget Sound Basin***, Olympia, WA, February, 1992.

Pennsylvania, Commonwealth of, Bureau of Soil and Water Conservation, ***Erosion and Sediment Pollution Control Program Manual***, Harrisburg, PA, April, 1990.

Stream Crossing, Temporary

A bridge, ford or temporary structure installed across a stream or watercourse for short-term use by construction vehicles or heavy equipment. To provide a means for construction vehicles to cross streams or watercourses without moving sediment into streams, damaging the streambed or channel, or causing flooding.

Where Practice Applies

Where heavy equipment must be moved from one side of a stream channel to another, or where light-duty construction vehicles must cross the stream channel frequently for a short period of time.

Planning Considerations

Contact the local Conservation Commission regarding any stream crossing or other work conducted in a wetland resource area. The Wetlands Protection Act requires that for any stream crossing or other work conducted in a wetland resource area, or within 100 feet of a wetland resource area, the proponent file a “Request for Determination of Applicability” or a “Notice of Intent” with the Conservation Commission.

Careful planning can minimize the need for stream crossings. Try to avoid crossing streams, whenever possible, complete the development separately on each side and leave a natural buffer zone along the stream.

Temporary stream crossings are necessary to prevent damage to stream banks and stream channels by construction vehicles crossing the stream. This reduces the sediment and other pollutants continually being tracked into the stream by vehicles. These are temporary crossings that represent channel constrictions which may cause obstruction to flow or erosion during periods of high flow. They should be in service for the shortest practical period of time and should be removed as soon as their function is complete.

Select locations for stream crossings where erosion potential is low. Evaluate stream channel conditions, overflow areas, and surface runoff control at the site before choosing the type of crossing. When practical, locate and design temporary stream crossings to serve as permanent crossings to keep stream disturbance to a minimum.

Plan stream crossings in advance of need, and when possible, construct them during dry periods to minimize stream disturbance and reduce cost. Ensure that all necessary materials and equipment are onsite before any work is begun. Complete construction in an expedient manner and stabilize the area immediately.

When construction requires dewatering of the site, construct a bypass channel before undertaking other work. If stream velocity exceeds that allowed for the inplace soil material, stabilize the bypass channel with riprap or other suitable material. After the bypass is completed and stable, the stream may be diverted.

Unlike permanent stream crossings, temporary stream crossings may be allowed to overtop during peak storm periods. The structure and approaches should, however, remain stable. Keep any fill needed in floodplains to a minimum to prevent upstream flooding and reduce erosion potential. Use riprap to protect locations subject to erosion from overflow.

Stream crossings are of three types: bridges, culverts, and fords. In selecting a stream crossing practice consider: frequency and kind of use, stream channel conditions; overflow areas; potential flood damage; and surface runoff control.

Culvert crossings

Culverts are the most common stream crossings. In many cases, they are the least costly to install, can safely support heavy loads, and are adaptable to most site conditions. Construction materials are readily available and can be salvaged. The installation and removal of culverts, however, causes considerable disturbance to the stream and surrounding area. Culverts also offer the greatest obstruction to flood flows and, therefore, are subject to blockage and washout.

Bridges

Where available materials and designs are adequate to bear the expected loadings, bridges are preferred for temporary stream crossing.

Bridges usually cause the least disturbance to the stream bed, banks, and surrounding area. They provide the least obstruction to flow and fish migration. They generally require little or no maintenance, can be designed to fit most site conditions, and can be easily removed and materials salvaged. Bridges, however, are generally the most expensive to design and construct. Also, they present a safety hazard if not adequately designed, installed, and maintained. If washed out, they cause a longer construction delay and are more costly to repair.

In steep watersheds it is recommended to tie a cable or chain to one corner of the bridge frame with the other end secured to a large tree or other substantial object. This will prevent flood flows from carrying the bridge downstream where it may cause damage to property.

Fords

Fords should only be used where crossings are infrequent.

Fords made of stabilizing material such as rock are sometimes used in steep areas subject to flash flooding, where normal flow is shallow (less than 3 inches deep) or intermittent. Fords are especially adapted for crossing wide, shallow watercourses.

When properly installed, fords offer little or no obstruction to flow, can safely handle heavy loadings, are relatively easy to install and maintain, and, in most cases, may be left in place at the end of construction.

Potential problems include:

Approach sections are subject to erosion. Do not use fords where bank height exceeds 5 feet.

Excavation for the installation of the riprap-gravel bottom and filter material causes major stream disturbance. In some cases, fords may be adequately constructed by shallow filling without excavation.

The stabilizing material is subject to washing out during storm flows and may require replacement.

Mud and other contaminants are brought directly into the stream on vehicles unless crossings are limited to no-flow conditions.

Design and Construction Recommendations

A stream crossing must be non-erosive and structurally stable, and must not introduce any flooding or safety hazard. Bridge design in particular should be undertaken only by a qualified engineer. The following standards apply only to erosion and sediment control aspects of bridges, culverts, and fords.

The anticipated life of a temporary stream crossing structure is usually considered to be 1 year or less. Remove the structure immediately after it is no longer needed.

As a minimum, design the structure to pass bank-full flow or peak flow, whichever is less, from a 2-year frequency, 24-hour duration storm without over topping. Ensure that no erosion will result from the 10-year peak storm.

Ensure that design flow velocity at the outlet of the crossing structure is nonerosive for the stream channel.

Consider overflow for storms larger than the design storm and provide a protected overflow area.

Planning and Site Preparation

Construct crossing when stream flow is low. Have all necessary materials and equipment on site before work begins.

Minimize clearing and excavation of streambanks, bed, and approach sections. Plan work to minimize crossing the stream with equipment. If possible, complete all work on one side of the stream before crossing to work on other side.

Location

The temporary crossing should be located where there will be the least disturbance to the stream channel, the stream banks, the flood plain adjacent to the channel, and adjacent wetlands.

Width

The minimum road width of a temporary crossing should be 12 feet.

Alignment

The temporary crossing should be at right angles to the stream whenever possible. If the approach conditions to the crossing are such that a perpendicular crossing is not possible, then a variation of up to 15 degrees is allowable.

Approaches

The centerline of the roadway approaches to the crossing should coincide with the crossing alignment for a distance of 30 feet in either direction. The maximum height of fill associated with the approaches should not exceed 2 feet. Limit surface runoff by installing diversions.

Surface Water and High Flow Diversion

A water diversion structure such as a swale should be constructed across the roadway at the end of both approaches to the crossing to allow stream flow exceeding the design storm to pass safely around the structure. These swales will also prevent surface water from flowing along the roadway and directly into the stream.

Locate swales not more than 50 feet from the waterway crossing. This will prevent roadway surface runoff from directly entering the waterway. The 50 feet is measured from the top of the waterway bank. If the roadway approach is constructed with a reverse grade away from the waterway, a separate diverting structure is not required.

Temporary Stream Diversion

Avoid diverting stream out of its natural channel by working on one-half of the installation at a time. If stream must be diverted, select most appropriate location considering extent of clearing, channel grade, amount of cut, and spoil disposal.

Excavate diversion channel starting at the lower end. If stream velocity exceeds that allowable for the temporary channel, stabilize with riprap. Temporary bypass channel must be stable for flows up to and including the 10-year storm.

The crossing site should be built in the dry streambed and stabilized before the stream is redirected to its normal course.

Sediment Traps

Where appropriate, install instream sediment traps immediately below stream crossings to reduce downstream sedimentation. Install before excavating or grading the approaches to a ford.

Excavate trap at least 2 feet below stream bottom and approximately twice the channel width for a minimum distance equal to one-half the length of crossing. Remove all spoil to an area outside the flood plain. Stabilize spoil appropriately.

Ensure that the flow velocity through the basin does not exceed the allowable flow velocity for the inplace soil material; otherwise it should not be excavated. In locations where trees or other vegetation must be removed, the sediment trap may be more damaging to the stream than if it were not installed.

Bridges and Culverts

Elevate bridge abutments or culvert fill 1 foot minimum above the adjoining streambank to allow storm overflow to bypass structure without damage. Culvert pipe should extend well beyond fill side slopes.

Protect disturbed streambanks, fill slopes and overflow areas with riprap or other suitable methods. Stabilize other disturbed areas as specified in the vegetation plan. Good surface stabilization is especially important at stream crossings as all eroded material directly enters the stream.

Earth fill for approaches should be free of roots, woody vegetation, oversized stones, organic material or other objectionable materials. The fill should be compacted by routing construction equipment over the fill so that the entire area of the fill is transversed by at least one wheel track or tread track of the equipment.

Bridges

A temporary bridge should be constructed at or above the stream bank elevation. Excavation of the stream bank should not be allowed for construction of this practice.

Span

Bridges should be constructed to span the entire width of the channel. If the width of the channel as measured from top of bank to top of bank exceeds 8 feet, then a footing, pier, or bridge support may be constructed in the stream bed. An additional footing or support will be allowed for each additional 8 feet of channel width. No footing, pier, or bridge support should be used in the stream bed for channel widths less than 8 feet.

Materials

Materials should be of sufficient strength to support the anticipated design loads. Stringers may be logs, sawn timber, prestressed concrete beams, or other appropriate materials. Decking materials must be butted tightly and securely fastened to the stringers to prevent soil, and other construction materials from falling into the stream channel below.

Bridge Anchors

The bridge should be anchored at only one end with either a steel cable or chain to prevent the bridge from floating away during flood events. The anchoring should be sufficient to prevent the bridge from floating downstream and possibly causing an obstruction in the stream channel below. Acceptable anchors are large trees, large boulders, or driven steel anchors.

Culverts

The minimum size for a culvert should be 18 inches. The maximum size for a culvert should be the largest pipe diameter that will fit into the existing channel without a significant amount of excavation required for its placement. Culverts may be circular or elliptical depending on the site requirements. Culverts should extend a minimum of one foot beyond the upstream and downstream toe of backfill placed around the culvert. Length should not exceed 40 feet.

Filter Cloth

Place filter cloth on the stream bed and the stream banks before installing the culvert and backfill. The filter cloth should extend a minimum of six inches and a maximum of one foot past the toe of the backfill.

Culvert Placement

The culvert should be installed on the natural stream bed grade. No overfall should be permitted at the downstream invert.

Backfill

No earth or fine-grained soil backfill should be used for temporary culvert crossings. Backfill should be clean, coarse aggregate. The backfill should be placed in maximum 6 inch lifts and compacted using a vibrating plate compactor. Material should be hand compacted around the haunches of the pipe, using particular care to assure that the line and grade of the pipe is maintained. The minimum allowable backfill over the pipe should be 12 inches or one-half pipe diameter which ever is greater. If multiple culverts are used they should be separated by a minimum of 12 inches of compacted aggregate backfill.

Appropriate headwalls or large rock should be placed on the upstream and downstream ends of the temporary fill crossing to protect against erosion during large flood flows.

Fords

Install geotextile fabric in channel to stabilize foundation, then apply well-graded, weather-resistant stone (3 to 6 inch) over fabric. Use only stabilization fabric, not filter fabric.

Stabilization

All areas disturbed by the installation of the temporary crossing should be stabilized using either rock, gravel, or vegetation as appropriate.

Removal

Remove temporary stream crossings as soon as they are no longer needed. Restore stream channel to original cross section and stabilize all disturbed areas. Appropriate measures should be taken to minimize effects on water quality when removing the crossing. Fords may be left in place if site conditions allow.

Temporary bypass channels should be permanently stabilized or removed. If removed, overfill by at least 10%, compact, and stabilize appropriately.

Leave in-stream sediment traps in place.

Common Trouble Points

Inadequate flow capacity and/or lack of overflow area around structure
Results in washout of culverts or bridge abutments.

Inadequate stabilization of overflow area
Results in severe erosion around bridges and culverts.

Exit velocity from culvert or bridges too high
Causes stream channel erosion and may eventually cause erosion of bridge or culvert fill.

Debris not removed after a storm
Clogging may cause washout of culverts or bridges.

Inadequate compaction under or around culvert pipes
Culverts wash out due to seepage and piping.

Stone size too small
Ford washes out.

Culvert pipes too short
Results in a crossing supported by steep, unstable fill slopes.

Maintenance

Inspect temporary crossing after each rainfall event for accumulation of debris, blockage, erosion of abutments and overflow areas, channel scour, riprap displacement, or piping along culverts.

Remove debris; repair and reinforce damaged areas immediately to prevent further damage to the installation.

Remove temporary stream crossings immediately when they are no longer needed. Restore the stream channel to its original cross-section, and smooth and stabilize all disturbed areas.

Leave in-stream sediment traps in place to continue capturing sediment.

References

Massachusetts Department of Environmental Protection, Office of Watershed Management, Nonpoint Source Program, Massachusetts ***Nonpoint Source Management Manual***, Boston, Massachusetts, June, 1993.

Minnick, E. L., and H. T. Marshall, ***Stormwater Management and Erosion Control for Urban and Developing Areas in New Hampshire***, Rockingham County Conservation District, August 1992.

North Carolina Department of Environment, Health, and Natural Resources, ***Erosion and Sediment Control Field Manual***, Raleigh, NC, February 1991.

North Carolina Sediment Control Commission, ***Erosion and Sediment Control Planning and Design Manual,*** Raleigh, NC, September, 1988.

Streambank Protection and Stabilization

Protecting and stabilizing banks of streams or excavated channels against scour and erosion. This practice may be accomplished by structural or vegetative means, or by a combination of both.

Purpose

- To protect streambanks from the erosive forces of moving water.
- To prevent the loss of land or damage to utilities, roads, buildings, or other adjacent facilities.
- To maintain the capacity of the channel.
- To control channel meander which would adversely affect downstream facilities.
- To reduce sediment loads causing downstream damages and pollution.
- To improve the stream for recreational use or as a habitat for fish and wildlife.

Where Practice Applies

This practice applies to natural or excavated channels where the streambanks are susceptible to erosion from the action of water, ice, or debris; excessive runoff from construction activities; or to damage from vehicular traffic.

This practice also applies to controlling erosion on shorelines where the problem can be solved with relatively simple structural measures, vegetation, or upland erosion control practices.

Advantages

Structural Methods

- Streambank protection can break wave action and reduce the velocity of flood flows.
- The reduction of velocity can lead to the deposit of water-borne soil particles.
- Water quality benefits of reduced erosion and downstream siltation.

Vegetative and Bioengineering Methods

Vegetative and bioengineering stabilization methods have additional advantages:

- Vegetative techniques are generally less costly and more compatible with natural stream characteristics.
- Roots and rhizomes stabilize streambanks.
- Certain reeds and bulrushes have the capability of improving water quality by absorbing certain pollutants such as heavy metals, detergents, etc.
- Plants regenerate themselves and adapt to changing natural situations, thus offering a distinct economic advantage over mechanical stabilization.
- Mechanical materials provide for interim and immediate stabilization until vegetation takes over.
- Once established, vegetation can outlast mechanical structures and requires little maintenance while regenerating itself
- Aesthetic benefits and improved wildlife and fisheries habitat.

Disadvantages/Problems

Structural Methods

- Cost of structural practices.
- Aesthetics.

Vegetative Methods

- Native plants may not be carried by regular nurseries and may need to be collected by hand, or obtained from specialty nurseries. Nurseries which carry these plants may require a long lead time for large orders.
- Flow retarding aspects of vegetated waterways need to be taken into account.
- Structural practices can be installed on steeper slopes than vegetative methods.
- Will not withstand as high flow velocities as structural methods.

Planning Considerations

Contact the local Conservation Commission regarding any stream crossing or other work conducted in a wetland resource area. The Wetlands Protection Act requires that for any stream crossing or other work conducted in a wetland resource area, or within 100 feet of a wetland resource area, the proponent file a "Determination of Applicability" or a "Notice of Intent" with the Conservation Commission.

Stream channel erosion problems vary widely in type and scale, and there is no one measure that works in all cases. Stabilization structures should be planned and designed by an engineer with experience in this field. Many of the practices involve the use of manufactured products and should be installed in accordance with the manufacturers specifications. Where long reaches of stream channels require stabilization, make detailed strewn studies.

Before selecting a structural stabilization technique, the designer should carefully evaluate the possibility of using vegetative stabilization in conjunction with structural measures to achieve the desired protection. Vegetative techniques are generally less costly and more compatible with natural stream characteristics.

Wherever possible, it is best to protect banks with living plants that are adapted to the site. Natural plant communities are aesthetically pleasing, provide a habitat for fish and wildlife, afford a self-maintaining cover, and are less expensive and damaging to the environment.

Special attention should be given to the preservation of fish and wildlife habitat, and trees of significant value for wildlife food or shelter, or for aesthetic purposes. Wildlife habitat can be improved by using woody plants and grasses that provide food and/or cover for native wildlife species. The retention of a 30-foot riparian zone along stream channels that is established to trees, shrubs, or grasses may provide wildlife, landscaping and water quality benefits.

Where construction will adversely affect a significant fish or wildlife habitat, mitigation measures should be included in the plan. Mitigation measures may include pools, riffles, flats, cascades, or other similar provisions.

Upstream development accelerates streambank erosion by increasing the velocity, frequency, and duration of flow. As a result, many natural streams that were stable become unstable following urbanization.

Most natural stream channels have bank-full capacity to pass the runoff from a 2-year recurrence interval storm. In a typical urbanizing watershed, however, stream channels may become subject to a 3 to 5 times as many bank-full flows if stormwater runoff is not properly managed. Stream channels that were once parabolic in shape and covered with vegetation may be transformed into wide rectangular channels with barren banks.

The following is a partial list of elements which may be involved in a plan for streambank protection.

- ***Obstruction removal*** - The removal of fallen trees, stumps, debris, minor ledge outcroppings and sand and gravel bars that may cause water turbulence and deflection, causing erosion of the bank.
- ***Clearing*** - The removal of trees and brush which adversely affect the growth of desirable bank vegetation.
- ***Bank sloping*** - The reduction of the slope of streambanks. Consideration should be given to flattening the side slope of the channel in some reaches to facilitate the establishment of vegetation or for the installation of structural bank protection.
- ***Fencing*** - Artificial obstructions to protect vegetation needed for streambank protection or to protect critical areas from damage from stock trails or vehicular traffic.
- ***Vegetation*** - Vegetative streambank stabilization is generally applicable where bankfull flow velocity does not exceed 6 feet/second and soils are erosion-resistant. Above 6 feet/second, structural measures are generally required.
- ***Riprap*** - Heavy angular stone placed on the streambank to provide armor protection against erosion.
- ***Jetties*** - Deflectors constructed of posts, piling, fencing rock, brush other materials which project into the stream to protect banks at curves and reaches subjected to impingement by high velocity currents.
- ***Revetments*** - Pervious or impervious structures built on or parallel to the stream to prevent scouring streamflow velocities adjacent to the streambank.
- ***Bioengineering*** - Bioengineering utilizes live plant parts in combination with structural methods to provide soil reinforcement and prevent surface erosion.

Structural measures, when employed correctly, immediately ensure satisfactory protection of stream banks. Structures are expensive to build, however, and to maintain. Without constant upkeep, they are exposed to progressive deterioration by natural agents. The materials used may prevent reestablishment of native plants and animals. Often structural measures destroy the appearance of the stream. Also, structural stabilization and channelization can alter the hydrodynamics of a stream and transfer erosion potential and associated problems downstream.

In contrast, the utilization of living plants instead of or in conjunction with structures has many advantages. The degree of protection, which may be low to start with, increases as the plants grow and spread. Repair and maintenance of structures is unnecessary where self-maintaining streambank plants are established. The protection provided by natural vegetation is more reliable and effective when the cover consists of natural plant communities adapted to their site.

Design Recommendations

Designs should be developed in accordance with the following principles:

- The grade must be controlled, either by natural or artificial means, before any permanent type of bank protection can be considered feasible; unless the protection can be safely and economically constructed to a depth well below the anticipated lowest depth of bottom scour.
- Streambank protection should be started at a stabilized or controlled point and ended at a stabilized or controlled point on the stream.
- Make protective measures compatible with other channel modifications planned or being carried out in other channel reaches.
- Ensure that the channel bottom is stable or stabilized by structural means before installing any permanent bank protection.
- Channel clearing, if needed to remove stumps, fallen trees, debris and bars which force the streamflow into the streambank, should be an initial element of the work.
- Changes in channel alignment should be made only after an evaluation of the effect on the land use, interdependent water disposal systems, hydraulic characteristics, and existing structures.
- Measures must be effective for the minimum design velocity of the peak discharge of the 10-year storm and be able to withstand greater floods without serious damage.
- Vegetative protection should be considered on the upper portions of eroding banks and especially on those areas which are subject to infrequent inundation.
- Stabilize all areas disturbed by construction as soon as complete.

Vegetative Methods

Channel reaches are often made stable by establishing vegetation where erosion potential is low and installing structural measures where the attack is more severe, such as the outside of channel bends and where the natural grade steepens. Vegetative methods must be effective for the design flow.

Bank reshaping and disturbance should be kept to a minimum except as necessary to install the practice. Where this is needed, banks should be shaped to result in a bank slope of 1:1 or flatter.

A temporary seeding should be used on all sites to provide protection while the permanent cover is becoming established.

Streambanks to be protected using grasses may need to be shaped on a 2:1 or 3:1 slope to provide for adequate seedbed preparation. The use of sod, instead of seeding, should be evaluated where economically justified and technically feasible.

The type of vegetative cover to be used should be based on the soil type, stream velocities, adjacent land use and anticipated level of maintenance to be performed.

A maintenance program should be established to provide sufficient moisture, fertility, replacement of dead or damaged plants and protection from damage by insects, diseases, machinery and human activities.

Streambanks stabilized using grasses should be evaluated as to whether an occasional or periodic mowing and fertilization are to be performed to maintain a healthy protective ground cover.

Sites should be protected from damage by vehicular and human traffic for the length of time necessary to get vegetative cover well established, but no less than one full growing season.

Staking

This involves inserting and tamping live, rootable vegetative cuttings into the ground. If correctly prepared and placed, the live stake will root and grow.

Dormant Woody Plantings

This is planting live, dormant-stem cuttings of woody plant species ½ to 3 inches or more in diameter.

Grasses

Where a good seedbed can be prepared, and on smaller streams where flow velocities are less, it may be feasible to stabilize eroding streambanks by seeding grasses above or in combination with dormant woody plantings. See recommendations in **Permanent Seeding** and in the supplementary material in Part 4.

A temporary seeding or mulching should be completed on those sites where a permanent seeding will not be established within 30 days following installation of a project. See **Temporary Seeding**.

Structural Methods

Generally applicable where flow velocities exceed 6 feet/second or where vegetative streambank protection is inappropriate.

Since each reach of channel requiring protection is unique, measures for structural streambank protection should be installed according to a plan based on specific site conditions.

Riprap

Riprap is the most common structural method used, but other methods such as gabions, deflectors, reinforced concrete, log cribbing, and grid pavers should be considered, depending on site conditions.

When possible, slope banks to 2:1 or flatter, and place a gravel filter or filter fabric on the smoothed slopes before installing riprap. Place the toe of the riprap at least 1 foot below the stream channel bottom or below the anticipated depth of channel degradation.

It is important to extend the upstream and downstream edges of riprap well into the bank and bottom. Extend riprap sections the entire length between well-stabilized points of the stream channel.

Gabions

These rectangular, rock-filled wire baskets are pervious, semi-flexible building blocks that can be used to armor the bed and/or banks of channels or act as deflectors to divert flow away from eroding channel sections. Design and install gabions in accordance with manufacturer's standards and specifications.

Reinforced concrete

May be used to armor eroding sections of the streambank by constructing retaining walls or bulk heads. Provide positive drainage behind these structures. Reinforced concrete may also be used as a channel lining for stream stabilization.

Log Cribbing

Retaining structure built of logs to protect streambanks from erosion. Vegetation can be planted between logs.

Grid pavers

Modular concrete units with interspersed void areas that can be used to armor the streambank while maintaining porosity and allowing the establishment of vegetation. These structures may be obtained in precast blocks or mats that come in a variety of shapes, or they may be formed and poured in place. Design and install in accordance with manufacturer's instructions.

Revetment

Structural support or armoring to protect an embankment from erosion. Riprap or gabions are commonly used. Gabions may be either stacked or placed as a mattress. Install revetment to a depth below the anticipated channel degradation and into the channel bed as necessary to provide stability.

Bioengineering Methods

Bioengineering combines structural and vegetative methods.

Streams in urban settings may carry an increase in runoff of such great magnitude that they cannot be maintained in a natural state. Soil bioengineering methods can provide for stabilization without complete visual degradation and higher effectiveness than purely mechanical techniques.

Construction Recommendations

Where possible: trees should be left standing; brush and stumps not removed; and construction operations carried on from one side, leaving vegetation on the opposite side.

Spoil resulting from excavation and shaping should be leveled or removed to permit free entry of water from adjacent land surface without excessive erosion or harmful ponding.

Trees and other fallen natural vegetation that do not deter stream flow should be left for fish habitat.

Vegetation should be established on all disturbed areas immediately after construction, weather permitting. If weather conditions are such as to cause a delay in the establishment of vegetation, the area should be mulched.

Topsoil

When soil conditions are particularly adverse for herbaceous vegetation, topsoil should be spread to a depth of 4 inches or more on critical areas to be seeded or sodded.

Mulching

Seeded side slopes should be mulched. Where streambanks are steeper than 2:1 or higher than 10 feet, the mulch should be anchored with paper twine fabric or equivalent material.

Maintenance

Check after every high-water event. Repairs should be made as quickly as possible after the problem occurs.

All temporary and permanent erosion and sediment control practices should be maintained and repaired as needed to assure continued performance of their intended function.

Streambanks are always vulnerable to new damage. Repairs are needed periodically. Banks should be checked after every high-water event is over. Gaps in the vegetative cover should be fixed at once with new plants, and mulched if necessary. Fresh cuttings from other plants on the bank can be used, or they can be taken from mother-stock plantings if they are available.

References

Massachusetts Department of Environmental Protection, Office of Watershed Management, Nonpoint Source Program, Massachusetts ***Nonpoint Source Management Manual***, Boston, Massachusetts, June, 1993.

North Carolina Sediment Control Commission, ***Erosion and Sediment Control Planning and Design Manual***, Raleigh, NC, September, 1988.

U.S. Department of Agriculture, Natural Resources Conservation Service, Champaign, IL, ***Urban Conservation Practice Standards***, 1994.

U.S. Department of Agriculture, Natural Resources Conservation Service, ***Engineering Field Handbook,*** *Chapter 18, Soil Bioengineering for Upland Slope Protection and Erosion Reduction* Washington, DC, October, 1992.

U.S. Department of Agriculture, Natural Resources Conservation Service, Champaign, IL, ***Urban Conservation Practice Standards***, 1994.

Washington State Department of Ecology, ***Stormwater Management Manual for the Puget Sound Basin***, Olympia, WA, February, 1992.

Subsurface Drain

A perforated conduit such as a pipe, tubing, or tile installed beneath the ground to intercept, collect, and convey excess ground water to a satisfactory outlet.

Purpose

- To provide a dewatering mechanism for draining excessively wet soils.
- To improve soil and water conditions for vegetative growth.
- To prevent sloughing of steep slopes due to ground water seepage.
- To improve stability of structures with shallow foundations by lowering the water table.

Where Practice Applies

Wherever excessive water must be removed from the soil.

The soil should have depth and sufficient permeability to permit installation of an effective drainage system at a depth of 2 to 6 feet.

An adequate outlet for the drainage system must be available either by gravity or by pumping. The quantity and quality of discharge should not damage the receiving stream.

Advantages

- An effective way to lower the water table.
- Subsurface drains often provide the only practical method of stabilizing excessively wet, sloping soils.

Disadvantages/Problems

Problems may be encountered with tree roots.

Planning Considerations

Contact the local Conservation Commission regarding any work conducted in a wetland resource area. The Wetlands Protection Act requires that for work conducted in a wetland resource area, or within 100 feet of a wetland resource area, the proponent file a “Request for Determination of Applicability” or a “Notice of Intent” with the Conservation Commission.

Subsurface drains usually consists of perforated, flexible conduit installed in a trench at a designed depth and grade. The trench around the conduit is often backfilled with a sand-gravel filter or gravel envelope. Backfill over the drain should be an open, granular soil of high permeability.

Subsurface drainage systems are of two types; relief drains and interceptor drains. Relief drains are used either to lower the water table in order to improve the growth of vegetation, or to remove surface water. They are installed along a slope and drain in the direction of the slope.

They can be installed in a gridiron pattern, a herringbone pattern, or a random pattern.

Interceptor drains are used to remove water as it seeps down a slope to prevent the soil from becoming saturated and subject to slippage. They are installed across a slope and drain to the side of the slope. They usually consist of a single pipe or series of single pipes instead of a patterned layout.

Design Recommendations

Subsurface drain should be sized for the required capacity. Design charts are available in Natural Resources Conservation Service references and from other sources. Manufacturers of special purpose drain configurations can provide instructions for design.

The minimum velocity required to prevent silting is 1.4 feet per second. The line should be installed on a grade to achieve at least this velocity.

The outlet of the subsurface drain should empty into a receiving channel, swale, or stable vegetated area adequately protected from erosion and undermining.

Construction Recommendations

The trench should be constructed on continuous grade with no reverse grades or low spots.

Soft or yielding soils under the drain should be stabilized with gravel or other suitable material.

Deformed, warped, or otherwise unsuitable pipe should not be used.

A sand-gravel filter at least three inches thick should be placed all around the pipe. Manufactured filters designed for the purpose, such as filter fabric, may be used as alternatives.

The trench should be backfilled immediately after placement of the pipe. No sections of pipe should remain uncovered overnight or during a rainstorm. Backfill material should be placed in the trench in such a manner that the drain pipe is not displaced or damaged.

Maintenance

Subsurface drains should be checked periodically to ensure that they are freeflowing and not clogged with sediment.

The outlet should be kept clean and free of debris.

Surface inlets should be kept open and free of sediment and other debris.

Trees located too close to a subsurface drain often clog the system with their roots. If a drain becomes clogged, relocate the drain or remove the trees as a last resort. Drain placement should be planned to minimize this problem.

Where drains are crossed by heavy vehicles, the line should be checked to ensure that it is not crushed.

References

Massachusetts Department of Environmental Protection, Office of Watershed Management, Nonpoint Source Program, ***Massachusetts Nonpoint Source Management Manual***, Boston, Massachusetts, June, 1993.

U.S. Environmental Protection Agency, S***torm Water Management For Construction Activities*** EPA-832-R- 92-005, Washington, DC, September, 1992.

Washington State Department of Ecology, ***Stormwater Management Manual for the Puget Sound Basin***, Olympia, WA, February, 1992.

Sump Pit

A temporary pit which is constructed to trap and filter water for pumping into a suitable discharge area. A perforated vertical standpipe is placed in the center of the pit to collect filtered water. The purpose of this practice is to remove excessive water in a manner that improves the quality of the water.

Where Practice Applies

Sump pits are constructed when water collects during the excavation phase of construction. This practice is particularly useful in urban areas during excavation for building foundations.

Planning Considerations

Discharge of water pumped from the standpipe should be to a suitable practice such as a sediment basin, sediment trap, or a stabilized area.

If water from the sump pit will be pumped directly to a storm drainage system, geotextile filter fabric should be wrapped around the standpipe to ensure clean water discharge. It is recommended that ¼ to ½ inch mesh hardware cloth wire be wrapped around and secured to the standpipe prior to attaching the filter fabric. This will increase the rate of water seepage into the standpipe.

Design Recommendations

A perforated vertical standpipe is placed in the center of the pit to collect filtered water. The standpipe will be a perforated 12 to 24-inch diameter corrugated metal or PVC plastic pipe. Water is then pumped from the pit to a suitable discharge area. The pit will be filled with coarse aggregate.

Maintenance

The sump pit will become clogged with sediment, oils, and organic matter over time. It is important to remove grass clippings and leaves from the surface of the aggregate in order to prolong its life.

The pit should be checked after every major storm to evaluate its effectiveness. If the pit and filter fabric become plugged with sediment, the pit should be rehabilitated. In some cases complete removal and replacement of the entire dry well may be necessary.

References

U.S. Department of Agriculture, Natural Resources Conservation Service, Champaign, IL, Urban Conservation Practice Standards, 1994.

Surface Roughening

Roughening a bare soil surface with horizontal grooves running across the slope, stair stepping, or tracking with construction equipment; or by leaving slopes in a roughened condition by not fine grading them.

Purpose

To aid the establishment of vegetative cover from seed, to reduce runoff velocity and increase infiltration, and to reduce erosion and provide for sediment trapping.

Where Practice Applies

All construction slopes require surface roughening to facilitate stabilization with vegetation, particularly slopes steeper than 3:1. This practice should also be done prior to forecasted storm events and before leaving a job site for a weekend.

Advantages

Surface roughening provides some instant erosion protection on bare soil while vegetative cover is being established.

It is an inexpensive and simple erosion control measure.

Disadvantages/Problems

While this is a cheap and simple method of erosion control, it is of limited effectiveness in anything more than a moderate storm.

Surface roughening is a temporary measure. If roughening is washed away in a heavy storm, the surface will have to be re-roughened and new seed laid.

Planning Considerations

Roughening a sloping bare soil surface with horizontal depressions helps control erosion by aiding the establishment of vegetative cover with seed, reducing runoff velocity, and increasing infiltration. The depressions also trap sediment on the face of the slope.

Consider surface roughening for all slopes. The amount of roughening required depends on the steepness of the slope and the type of soil. Stable, sloping rocky faces may not require roughening or stabilization, while erodible slopes steeper than 3:1 require special surface roughening.

Roughening methods include stair-step grading, grooving, and tracking. Equipment such as bulldozers with rippers or tractors with disks may be used. The final face of slopes should not be bladed or scraped to give a smooth hard finish.

Graded areas with smooth, hard surfaces give a false impression of “finished grading” and a job well done. It is difficult to establish vegetation on such surfaces due to reduced water infiltration and the potential for erosion. Rough slope surfaces with uneven soil and rocks left in place may appear unattractive or unfinished at first, but they encourage water infiltration, speed the establishment of vegetation, and decrease runoff velocity.

Rough, loose soil surfaces give lime, fertilizer, and seed some natural coverage. Niches in the surface provide microclimates which generally provide a cooler and more favorable moisture level than hard flat surfaces; this aids seed germination.

Construction Recommendations

Roughening methods include stair-step grading, grooving, and tracking. Factors to be considered in choosing a method are slope steepness, mowing requirements, and whether the slope is formed by cutting or filling.

Graded areas with slopes greater than 3:1 but less than 2:1 should be roughened before seeding. This can be accomplished in a variety of ways, including “track walking,” or driving a crawler tractor up and down the slope, leaving a pattern of cleat imprints parallel to slope contours.

Graded areas steeper than 2:1 should be stair-stepped with benches. The stair-stepping will help vegetation become established and also trap soil eroded from the slopes above.

Disturbed areas which will not require mowing may be stair-step graded, grooved, or left rough after filling.

Stair-step grading is appropriate for soils containing large amounts of soft rock. Each "step" catches material that sloughs from above, and provides a level site where vegetation can become established. Stairs should be wide enough to work with standard earth moving equipment.

Areas which will be mowed (these areas should have slopes less steep than 3:1) may have small furrows left by disking, harrowing, raking, or seed-planting machinery operated on the contour.

It is important to avoid excessive compacting of the soil surface when scarifying. Tracking with bulldozer treads is preferable to not roughening at all, but is not as effective as other forms of roughening, as the soil surface is severely compacted and runoff is increased.

Maintenance

Areas which are graded in this manner should be seeded as quickly as possible.

Regular inspections should be made. If rills appear, they should be regraded and reseeded immediately.

References

Massachusetts Department of Environmental Protection, Office of Watershed Management, Nonpoint Source Program, ***Massachusetts Nonpoint Source Management Manual, Boston***, Massachusetts, June, 1993.

U.S. Environmental Protection Agency, ***Storm Water Management For Construction Activities***, EPA-832-R- 92-005, Washington, DC, September, 1992.

Washington State Department of Ecology, ***Stotmwater Management Manual for the Puget Sound Basin***, Olympia, WA, February, 1992.

Terrace

A ridge and channel constructed across a slope and used to convey runoff water. Reduces erosion damage by intercepting surface runoff and conducting it to a stable outlet at a nonerosive velocity.

Where Practice Applies

Terraces are utilized on slopes having a water erosion problem. They should not be constructed on deep sands or on soils that are too stony, steep, or shallow to permit practical and economical installation and maintenance. Terraces should be used only where suitable outlets are or will be made available.

Advantages

Terraces lower the velocity of runoff, increase the distance of overland flow, and reduce slope length. They also hold moisture and minimize sediment.

Disadvantages/Problems

May significantly increase cut and fill costs and cause sloughing if excessive water infiltrates soils.

Design Recommendations

Spacing

The maximum recommended spacing is a maximum vertical distance of 20 feet between terraces or other practices such as a diversion, dike, or sediment fence at the top or bottom of a slope.

Channel Grade

Channel grades may be either uniform or variable with a maximum grade of 0.6 feet per 100 feet length. For short distances, terrace grades may be increased to improve alignment. The channel velocity should not exceed that which is nonerosive for the soil type with the planned treatment.

Outlet

All terraces should have adequate outlets. Such an outlet may be a grassed waterway, vegetated area, or subsurface drain outlet. In all cases the outlet must convey runoff from the terrace or terrace system to a point where the outflow will not cause damage. Vegetative cover should be used in the outlet channel.

The design elevation of the water surface of the terrace should not be lower than the design elevation of the water surface in the outlet at their junction, when both are operating at design flow.

Vertical spacing may be increased as much as 0.5 feet or 10 percent, whichever is greater, to provide better alignment or location, to avoid obstacles, to adjust for equipment size, or to reach a satisfactory outlet.

Capacity

The terrace should have enough capacity to handle the peak runoff expected from a 2-year, 24-hour design storm without overtopping.

Cross-Section

The terrace cross-section should be proportioned to fit the land slope. The ridge height should include a reasonable settlement factor and "freeboard" (vertical distance between top of ridge and water elevation in the channel at dewsign flow).

The minimum cross-sectional area of the terrace channel should be 8 square feet for land slopes of 5 percent or less, 7 square feet for slopes from 5 to 8 percent, and 6 square feet for slopes steeper than 8 percent. The terrace should be constructed wide enough to be maintained using a small bulldozer.

Maintenance

Maintenance should be performed as needed. Terraces should be inspected regularly; at least once a year, and after large storm events.

References

Minnick, E. L., and H. T. Marshall, ***Stormwater Management and Erosion Control for Urban and Developing Areas in New Hampshire***, Rockingham County Conservation District, August 1992.

Washington State Department of Ecology, ***Stormwater Management Manual for the Puget Sound Basin***, Olympia, WA, February, 1992.

Topsoiling

Preserving and using topsoil to provide a suitable growth medium and enhance final site stabilization with vegetation.

Where Practice Applies

- Where a sufficient supply of quality topsoil is available.
- Where slopes are 2:1 or flatter.
- Where the subsoil or areas of existing surface soil present the following problems:
    - The structure, pH, or nutrient balance of the available soil cannot be amended by reasonable means to provide an adequate growth medium for the desired vegetation.
    - The soil is too shallow to provide adequate rooting depth or will not supply necessary moisture and nutrients for growth of desired vegetation.
    - The soil contains substances toxic to the desired vegetation.
- Topsoiling is strongly recommended where ornamental plants or high-maintenance turf will be grown.

Advantages

Advantages of topsoil include higher organic matter and greater available water-holding capacity and nutrient content.

Topsoil stockpiling ensures that a good growth medium will be available for establishing plant cover on graded areas.

The stockpiles can be used as noise and view baffles during construction.

Disadvantages/Problems

Stripping, stockpiling, and reapplying topsoil, or importing topsoil may not always be cost-effective. It may also create an erosion problem if improperly secured.

Unless carefully located, storage banks of topsoil may also obstruct site operations and therefore require double handling.

Topsoiling can delay seeding or sodding operations, increasing exposure time of denuded areas.

Most topsoil contains some weed seeds.

Planning Considerations

Topsoiling may be required to establish vegetation on shallow soils, soils containing potentially toxic materials, very stony areas, and soils of critically low pH.

Topsoil is the surface layer of the soil profile, generally characterized as being darker than the subsoil due to the presence of organic matter. It is the major zone of root development and biological activities for plants, carrying much of the nutrients available to plants, and supplying a large share of the water used by plants. It should be stockpiled and used wherever practical for establishing permanent vegetation.

The need for topsoiling, should be evaluated. Take into account the amount and quantity of available topsoil and weigh this against the difficulty of preparing a good seedbed on the existing subsoil. Where a limited amount of topsoil is available, it should be reserved for use on the most critical areas. In many cases topsoil has already been eroded away or, as in wooded sites, it may be too trashy.

Make a field exploration of the site to determine if there is surface soil of sufficient quantity and quality to justify stripping. Topsoil should be spread at a depth of 2 to 4 inches. More topsoil will be needed if the subsoil is rocky.

Topsoil should be friable and loamy (loam, sandy loam, silt loam, sandy clay loam, clay loam). Areas of natural ground water recharge should be avoided.

Allow sufficient time in scheduling for topsoil to be spread and bonded prior to seeding, sodding, or planting.

Do not apply topsoil if the subsoil has a contrasting texture. Sandy topsoil over clayey subsoil is a particularly poor combination; water can creep along the junction between the soil layers and causes the topsoil to slough.

Stripping

Stripping should be confined to the immediate construction area. A 4 to 6 inch stripping depth is common, but depth may vary depending on the particular soil. All surface runoff control structures should be in place prior to stripping.

Stockpiling

Locate the topsoil stockpile so that it does not interfere with work on the site.

Side slopes of the stockpile should not exceed 2:1.

Surround all topsoil stockpiles with an interceptor dike with gravel outlet and silt fence.

Either seed or cover stockpiles with clear plastic or other mulching materials within 7 days of the formation of the stockpile.

Placement

Topsoil should not be placed while in a frozen or muddy condition, when the subgrade is excessively wet, or when conditions exist that may otherwise be detrimental to proper grading or proposed sodding or seeding.

Do not place topsoil on slopes steeper than 2:1, as it will tend to slip off.

If topsoil and subsoil are not properly bonded, water will not infiltrate the soil profile evenly and it will be difficult to establish vegetation. The best method is to actually work the topsoil into the layer below for a depth of at least 6 inches.

Maintenance

Maintain protective cover on stockpiles until needed.

References

Massachusetts Department of Environmental Protection, Office of Watershed Management, Nonpoint Source Program, ***Massachusetts Nonpoint Source Management Manual,*** Boston, Massachusetts, June, 1993.

Washington State Department of Ecology, ***Stormwater Management Manual for the Puget Sound Basin***, Olympia, WA, February, 1992.

Tree and Shrub Planting

Stabilizing disturbed areas by establishing a vegetative cover of trees or shrubs.

Purpose

- To stabilize the soil with vegetation other than grasses or legumes.
- To provide food and shelter for wildlife.
- To provide windbreaks or screens.

Where Practice Applies

Trees and shrubs may be used:

- On steep or rocky slopes,
- Where mowing is not feasible,
- As ornamentals for landscaping purposes, or
- In shaded areas where grass establishment is difficult.

Advantages

Trees and shrubs can provide superior, low-maintenance, long-term erosion protection. They may be particularly useful where site aesthetics are important.

Besides their erosion and sediment control values, trees and shrubs also provide natural beauty and wildlife benefits.

Disadvantages/Problems

Except for quick-growing species; it may take a number of years for trees to reach full size.

Trees and shrubs may be expensive to purchase and establish. They may also be more subject to theft than materials used in other practices.

Planning Considerations

There are many different species of plants from which to choose, but care must be taken in their selection. It is essential to select planting material suited to both the intended use and specific site characteristics.

None of these plants, however, is capable of providing the rapid cover possible by using grass and legumes. Vegetative plans must include close-growing plants or an adequate mulch with all plantings.

When used for natural beauty and wildlife benefits, trees and shrubs are usually more effective when planted in clumps or blocks.

Species Selection

When erosion or sediment control is not of primary, immediate concern; areas may be stabilized using rugged, fast-growing trees and shrubs that once established have a good record of taking care of themselves. These plants may not be the best ornamentals, but establishment can usually be made with these low-maintenance trees and shrubs.

In some cases, it may be desirable to use trees and shrubs as screening plants to shield sites such as gravel pits from public view. These plants should be given the best possible attention at planting time, with good soil water, and mulching.

Shrub and tree species recommendations for various soil conditions, densities, and arrangements will be found in Part 4 of this document.

Planting

Trees and shrubs will do best in topsoil. If no topsoil is available, they can be established in subsoil with proper amendment. If trees and shrubs are to be planted in subsoil, particular attention should be paid to amending the soil with generous amounts of organic matter. Mulches should also be used.

Good quality planting stock should be used. For mass plantings one or two-year old deciduous seedlings, and 3 or 4-year old coniferous transplants should be used. For smaller planting groups or individuals specimen plants, bare rooted, container grown or balled and burlaped stock may be preferred because of their larger size. Stock should be kept cool and moist from time of receipt until planted.

Competing vegetation, if significant, should be destroyed or suppressed prior to planting by scalping a small area where the plant is to be placed.

Stock should be planted in the spring by May 15. No fertilizer should be used at the time of planting unless it is a slow-release type formulated for trees and shrubs.

Plants should be planted at the approximate depth they were growing in the nursery; the roots should be uncrowded; the soil should be firmly packed against the roots after setting.

Shrubs should be mulched to a depth of 4 inches or more with woodchips, bark, peat moss or crushed stone. Mulch to the edge of the planting at, but not less than, one foot from the trunk.

Maintenance

Deciduous plants should be fertilized six months to one year after planting with ¼ pound of a 10-6-8 fertilizer per plant (or 25 lbs. per 1,000 sq. ft. for block plantings) or the equivalent. A slow release fertilizer is preferred. Evergreens should be fertilized half as much.

The planting should be inspected after the first and second growing seasons. Replanting and repairs, as needed to provide adequate cover, should be scheduled. Fertilizer should be applied to shrubs every 3 to 5 years after planting.

References

Massachusetts Department of Environmental Protection, Office of Watershed Management, Nonpoint Source Program, ***Massachusetts Nonpoint Source Management Manual,*** Boston, Massachusetts, June, 1993.

Vegetated Swale

Vegetated swales are broad channels, either natural or constructed, with dense vegetation; whose purpose is to retard or impound concentrated runoff and dispose of it safely into the drainage system.

Purpose

To reduce runoff velocities, and reduce potential erosion from the discharge of runoff.

Vegetated swales may also remove some particulate pollutants from stormwater runoff and increase infiltration.

Where Practice Applies

This practice applies to all sites where a dense stand of vegetation can be established and where either a stable outlet exists or can be constructed as a suitable conveyance system to safely dispose of the runoff flowing from the swale.

The swale can be used by itself or in combination with erosion and sediment control practices:

- In residential areas of low to moderate density where the percentage of impervious cover is relatively small.
- In a drainage easement at the side or back of residential lots.
- Adjacent to parking areas.
- Along highway medians as an alternative to curb and gutter drainage systems.

Planning Considerations

The vegetated swale and the grassed waterway are very similar. The difference in the two practices is mainly in purpose. The vegetated swale is used for water quality improvement and peak runoff reduction; accomplished by limiting the velocity in the swale. The grassed waterway or outlet is used to convey runoff at a non-erosive velocity.

Vegetated swales are best suited on small drainage areas where the amount of impervious cover is relatively small. If dense vegetation cannot be established and maintained in the swale, then its effectiveness is severely reduced.

The seasonal high water table should be at least two feet below the bottom of the swale in order to provide for more effective infiltration and treatment of the runoff and to provide better growing conditions for the vegetation. Subsurface drainage may be needed to control high water table and improve the condition of the swale.

The swale should be constructed prior to any other channel or facility which will drain into it and flow should be diverted out of the swale until adequate vegetation is established.

Vegetated swales should generally not receive construction-stage runoff; if they do, presettling of sediments should be provided.

Swales should be protected from siltation by a sediment pond or basin when the erosion potential is high; otherwise, presettling is not generally needed for normal operation.

Soil moisture should be sufficient to provide water requirements during the dry season, but where the water table is not so high as to cause long periods of soil saturation. Irrigate if moisture is inadequate during summer drought. If saturation will be extended or the slope is minimal but grasses are still desired, consider subdrains.

Prevent bare areas by avoiding gravel, rocks, and hardpan near the surface.

Design Recommendations

The minimum capacity should be that required to convey the peak runoff expected from a 10-year frequency 24-hour duration storm.

The maximum design velocity for a vegetated swale should be one foot per second during passage of the 10-year frequency storm.

The minimum recommended length of a vegetated swale is 200 feet. If a shorter length must be used, increase swale cross-sectional area by an amount proportional to the reduction in length below 200 feet, in order to obtain the same water residence time.

The channel slope should normally be between 2 and 4 percent. A slope of less than 2 percent can be used if underdrains are placed beneath the channel to prevent ponding. A slope of greater than 4 percent can be used if check dams are placed in the channel to slow the flows accordingly.

Install log or rock check dams approximately every 50 feet, if longitudinal slope exceeds 4 percent. Adjust check dam spacing in order not to exceed 4 percent slope within each channel segment between dams.

The cross section for a vegetated swale may be parabolic, triangular, or trapezoidal.

If flow is introduced to the swale via curb cuts, place pavement slightly above the swale elevation. Curb cuts should be at least 12 inches wide to prevent clogging.

Subsurface drainage measures should be provided if sites have high water tables or seepage problems, except where water-tolerant vegetation such as reed canary grass can be used. There should be no base flow present in the swale.

Vegetative Recommendations

Swales should be vegetated with an appropriate grass mixture: The swale should be mulched if necessary for establishment of good quality vegetation. A temporary diversion should be used to divert runoff away from the swale until vegetation is established that is capable of preventing erosion.

Select vegetation according to what will best establish and survive in the site conditions. Select fine, close-growing, water-resistant grasses. If a period of soil saturation is expected, select emergent wetland plant species. Protect these plants during establishment by netting.

Select a grass height of 6 inches or less and a flow depth of less than 5 inches. Grasses over that height tend to flatten down when water is flowing over them, which prevents sedimentation.

Construction Recommendations

Avoid compaction during construction. If compaction occurs, till before planting to restore lost soil infiltration capacity.

Divert runoff during the period of vegetation establishment. Sodding is an alternative for rapid stabilization. Where it is not possible to divert runoff, cover graded and seeded areas with a suitable erosion control slope covering material.

Maintenance

Timely maintenance is important to keep the vegetation in the swale in good condition. Mowing should be done frequently enough to keep the vegetation in vigorous condition and to control encroachment of weeds and woody vegetation, however it should not be mowed too closely so as to reduce the filtering effect.

Fertilize on an "as needed" basis to keep the grass healthy. Over-fertilization can result in the swale becoming a source of pollution.

The swale should be inspected periodically and after every major storm to determine the condition of the swale. Rills and damaged areas should be promptly repaired and re-vegetated as necessary to prevent further deterioration.

Vegetated swales planted in grasses must be mowed regularly during the summer to promote growth and pollutant uptake. Plan on mowing as needed to maintain proper height. Remove cuttings promptly, and dispose in a way so that no pollutants can enter receiving waters.

Remove sediments during summer months when they build up to 6 inches at any spot or cover vegetation. If the equipment leaves bare spots, re-seed them immediately.

Inspect periodically, especially after periods of heavy runoff. Remove sediments, fertilize, and reseed as necessary. Be careful to avoid introducing fertilizer to receiving waters or ground water.

Clean curb cuts when soil and vegetation buildup interferes with flow introduction.

References

Massachusetts Department of Environmental Protection, Office of Watershed Management, Nonpoint Source Program, ***Massachusetts Nonpoint Source Management Manual,*** Boston, Massachusetts, June, 1993.

Minnick, E. L., and H. T. Marshall, ***Stormwater Management and Erosion Control for Urban and Developing Areas in New Hampshire***, Rockingham County Conservation District, August 1992.

Washington State Department of Ecology, ***Stormwater Management Manual for the Puget Sound Basin***, Olympia, WA, February, 1992.

Water Bar

A ridge or ridge and channel constructed diagonally across a sloping road or utility right-of-way that is subject to erosion. Used to prevent erosion on long, sloping right-of-way routes by diverting runoff at selected intervals.

Where Practice Applies

- Where runoff protection is needed to prevent erosion on sloping access right-of-ways.
- On sloping areas generally less than 100 feet in width.

Disadvantages/Problems

Need maintenance periodically for vehicle wear.

Planning Considerations

Narrow rights-of-way on long slopes used by vehicles can be subject to severe erosion. Surface disturbance and tire compaction promote gully formation by increasing the concentration and velocity of runoff.

Water bars are constructed by forming a ridge or ridge and channel diagonally across the sloping right-of-way. Each outlet should be stable, and should be able to handle the cumulative effect of upslope diversion outlets. The height and side slopes of the ridge and channel are designed to divert water and to allow vehicles to cross.

Design Recommendations

Height - 18 inches minimum from channel bottom to top of settled ridge.
Side slopes - 2:1 or flatter (3:1 or flatter where vehicles cross).
Spacing - For right-of-way widths less than 100 feet; spacing as follows:

Slope (%)	Diversion Spacing (feet)
< 5	125
5 to 10	100
10 to 20	75
20 to 35	50
>35	25

Base width of ridge - 6 feet minimum.
Grade - Constant or slightly increasing, not to exceed 2%.
Outlet - Diversion must cross the full access width and extend to a stable outlet.

Installation

Construct the diversion system as soon as the access right-of-way has been cleared and graded. Locate first diversion at required distance from the slope crest depending on steepness of right-of-way slope. Set crossing angle to keep positive grade less than 2% (approximately 60-degree angle preferred).

Mark location and width of ridge and disk the entire length.

Fill and compact ridge above design height and compact with wheeled equipment to the design cross section.

Construct diversions on constant or slightly increasing grade not to exceed 2%. Avoid reverse grades.

Set direction of water bars to utilize the most stable outlet locations. If necessary, adjust length of waterbars or make small adjustments to spacing.

Do not allow runoff from upslope water bars to converge with downslope water bar outlets.

Construct sediment traps or outlet stabilization structures as needed.

Seed and mulch the ridge and channel immediately.

Common Trouble Points

Overtopping ridge where diversion crosses low areas -
Build water bars to grade at all points

Erosion between water bars -
Spacing too wide for slope. Install additional water bars.

Ridge worn down -
Channel filled where vehicles cross; surface not stable; or side slopes too steep: may need gravel.

Erosion at outlets -
Install outlet stabilization structure or extend upslope water bar so runoff will not converge on lower outlets.

Erosion in channel -
Grade too steep. Realign water bar.

Maintenance

Inspect water bars periodically for vehicle wear. Inspect for erosion and sediment deposition after heavy rains.

Remove debris and sediment from diversion channel and sediment traps, repair ridge to positive grade and cross section. Add gravel at crossing areas and stabilize outlets as needed.

Repair and stabilize water bars immediately if right-of-way is disturbed by installation of additional utilities.

In removing temporary water bars, grade ridge and channel to blend with natural ground. Compact channel fill and stabilize disturbed areas with vegetation. Water bars should not be removed until all disturbed areas draining to them have been stabilized, inspected, and approved.

If water bars are designed for permanent use, correct any erosion problems, stabilize outlets, and apply permanent seeding.

References

Massachusetts Department of Environmental Protection, Office of Watershed Management, Nonpoint Source Program, ***Massachusetts Nonpoint Source Management Manual***, Boston, Massachusetts, June, 1993.

North Carolina Department of Environment, Health, and Natural Resources, ***Erosion and Sediment Control Field Manual***, Raleigh, NC, February 1991.

Waterway, Grassed

A natural or constructed waterway or outlet shaped or graded and established in suitable vegetation as needed for the safe disposal of runoff water. Used to convey and dispose of concentrated runoff to a stable outlet without damage from erosion, deposition, or flooding.

Where Practice Applies

This practice applies to construction sites where:

- Concentrated runoff will cause damage from erosion or flooding,
- A vegetated lining can provide sufficient stability for the channel cross section and grade,
- Slopes are generally less than 5 percent, and
- Space is available for a relatively large cross section.

Typical uses include roadside ditches, channels at property boundaries, and outlets for diversions.

Planning Considerations

Grass-lined channels resemble natural systems and are usually preferred where design velocities are suitable. Select appropriate vegetation and construct channels early in the construction schedule before grading and paving increase runoff rates.

Two major considerations for a grassed waterway are adequate capacity and sufficient erosion resistance.

The channel cross section should be wide and shallow with relatively flat side slopes so surface water can enter over the vegetated banks without causing erosion.

Vegetation should be established before runoff is allowed to flow in the waterway.

Supplemental measures may be needed with this practice. These may include but not be limited to such things as:

- Grade control structures,
- Level spreaders,
- Paved or rock-lined bottom, or
- Subsurface drain to eliminate wet spots and permit growing suitable vegetation.

Primary considerations for a stormwater conveyance channel are the volume, velocity, and duration of flow expected in the channel. In addition, there are several other factors that should be taken into consideration when planning a channel. These include soil characteristics, safety, aesthetics, availability of land, compatibility with land use and surrounding environment, and maintenance requirements. The type of cross section that is selected depends on these factors.

Triangular sections are used where the volume of flow is relatively small, such as in roadside ditches. Vegetation can be used in these ditches where the velocities are low. On steep slopes, however, where higher velocities are encountered; it may be necessary to line the channel with rock riprap, concrete, asphalt or other erosion resistant lining. Triangular cross-sections may be more prone to erosion because during small flows, the flow is concentrated in the narrow v-section.

Parabolic sections are suited for higher flows, but require the use of more land because the channels are generally shallow and wide. These channels seem to blend better in natural settings when grass mixtures are used as a lining. When velocities exceed the capability of vegetation, rock riprap can be used as a lining. When there is a continuous base flow in the channel it may be possible to use a combination of rock riprap and vegetation as a lining. The base flow would be carried by the riprap section and the higher flows by the vegetated section as long as the vegetation is capable of withstanding the velocity.

A trapezoidal channel is usually used where the flows are relatively large and at higher velocities. These channels are usually lined with materials other than vegetation. Trapezoidal channels usually take up less land than either triangular or parabolic channels.

Regardless of the channel shaped selected, the outlet should be checked to determine if it is stable. It may be necessary to have some type of energy dissipater to prevent scour to the receiving outlet if there is an overflow or if velocities in the contributing channel are higher than the outlet can withstand.

Design Recommendations

Capacity - The minimum capacity should be that required to convey the peak runoff expected from a storm of 10-year frequency. Peak runoff values should be determined by accepted methods.

To provide for loss in channel capacity due to vegetal matter accumulation, sedimentation, and normal seedbed preparation, the channel depth and width may be increased proportionally to maintain the hydraulic properties of the waterway. In parabolic channels, this may be accomplished by adding 0.3 foot to the depth and 2 feet to the top width of the channel. This is not required on waterways located in natural watercourses.

Cross Section - The cross section may be parabolic, triangular, or trapezoidal.

Grade - Generally restricted to slopes 5% or less.

Sideslopes - Generally 3:1 or flatter to establish and maintain vegetation and facilitate mowing.
Where a paved or stone-lined bottom is used in combination with vegetated side slopes, it should be designed to handle the base flow, snowmelt, or runoff from a one-year frequency storm, whichever is greater. The flow depth of the paved section should be a minimum of 0.5 feet.

Width - The bottom width of waterways or outlets should not exceed 50 feet unless multiple or divided waterways or other means are provided to control meandering of low flows within this limit.

Drainage - Subsurface drainage measures should be provided in the design for sites having high water table or seepage problems, except where water-tolerant vegetation such as reed canarygrass can be used. Where there is base flow present or long duration flows are expected, a stone center or underground outlet should be used.

Outlet - The outlet must be stable. Channels carrying sediment must empty into sediment traps.

Stabilization - Waterways should be stabilized with vegetative measures or stone centers. If a vegetated lining is supplemented by stone center, or other erosion-resistant materials, the velocity may be increased by 2.0 ft/sec.

Construction Recommendations

Remove all trees, brush, stumps, and other objectionable material from the foundation area and dispose of properly.

Install traps or other measures to protect grassed waterways from sediment.

The channel section should be free of bank projections or other irregularities which prevent normal flow.

Excavate and shape channel to dimensions shown on plans. Overcut entire channel 0.2 ft to allow for bulking during seedbed preparation and growth of vegetation. If installing sod, overcut channel the full thickness of the sod.

Remove and properly dispose of excess soil so that surface water may enter the channel freely.

Earth removed and not needed in construction should be spread or disposed of so as not to interfere with the functioning of the waterway.

Fills placed in waterways should be thoroughly compacted in order to prevent unequal settlement that could cause damage in the completed waterway.

Protect all concentrated inflow points along channel by installing a temporary liner, riprap, sod, or other appropriate measures.

Stabilize outlets and install sediment traps as needed during channel installation.

Vegetate the channel immediately after grading. Smooth slopes facilitate maintenance.

Establishing Vegetation

Waterways should be protected by vegetative means as soon after construction as practical, and before diversions or other channels are outletted into them. Consideration should be given to jute matting, excelsior matting, or sodding of channel to provide erosion protection as soon after construction as possible.

Install sod instead of seeding in critical areas, particularly where slopes approach 5%.

Seeding, fertilizing, mulching, and sodding should be in accord with applicable vegetative standards for permanent cover. See Permanent Seeding.

One-half to one bushel of oats should be added to the basic mixture for quick cover and to help anchor the mulch.

Very moist waterways are often best vegetated by working rootstocks of reed canarygrass into the seedbed.

When soil conditions are unfavorable for vegetation (such as very coarse-textured subsoil material), topsoil should be spread to a depth of 4 inches or more on at least the center half of parabolic shaped channels or on the entire bottom of trapezoidal shaped channels.

Seeded channels should be mulched. For critical sections of large channels, and for steep channels, the mulch should be anchored by cutting it lightly into the soil surface, or by covering with paper twine fabric or equivalent material; or jute netting should be used.

Common Trouble Points

Erosion occurs in channel before vegetation is fully established
Repair, reseed, and install temporary liner.

Gullying or head cutting in channel
Grade too steep for grass lining (steep grade produces excessive velocity). Channel and liner should be redesigned.

Sideslope caving
May result from any of the following:
- channel dug in unstable soil (high water table),
- banks too steep for site conditions, or
- velocity too high, especially on outside of channel curves.

Overbank erosion, spot erosion, channel meander, or flooding
Avoid debris and sediment accumulation. Stabilize trouble spots and revegetate. Riprap or other appropriate measures may be required.

Ponding along channel
Approach not properly graded, surface inlets blocked.

Erosion at channel outlet
Install outlet stabilization structure.

Sediment deposited at channel outlet
Indicates erosion in channel or watershed. Find and repair any channel erosion. Stabilize watershed, or install temporary diversions and sediment traps to protect channel from sediment-laden runoff.

Maintenance

During the initial establishment period, flow should be diverted out of the channel if at all possible to allow for a good stand of grass. If this is not possible use matting. In any case during the establishment period, the channel should be checked after every rainfall to determine if the grass is still in good condition and in place.

After the vegetation has become established, the channel should be checked periodically and after every major storm to see if damage has occurred. Any damaged areas should be repaired and revegetated immediately.

Maintenance of the vegetation in the grassed waterway is extremely important in order to prevent rilling, erosion, and failure of the waterway.

Mowing should be done frequently enough to control encroachment of weeds and woody vegetation and to keep the grasses in a vigorous condition. The vegetation should not be mowed too closely so as to reduce the erosion resistance in the waterway.

Periodic applications of lime and fertilizer may be needed to maintain vigorous growth.

Remove all significant sediment and debris from channel to maintain the design cross section and grade and prevent spot erosion.

Existing waterways can often be best repaired by working sods of witchgrass (quackgrass) into the seedbed.

It is important to check the channel outlet and all road crossings for blockage, sediment, bank instability, and evidence of piping or scour holes.

References

Massachusetts Department of Environmental Protection, Office of Watershed Management, Nonpoint Source Program, ***Massachusetts Nonpoint Source Management Manual***, Boston, Massachusetts, June, 1993.

Minnick, E. L., and H. T. Marshall, S***tormwater Management and Erosion Control for Urban and Developing Areas in New Hampshire***, Rockingham County Conservation District, August 1992.

North Carolina Department of Environment, Health, and Natural Resources, ***Erosion and Sediment Control Field Manual***, Raleigh, NC, February 1991.

Waterway, Lined

A waterway with an erosion resistant lining of concrete, stone, or other permanent material. The lined section extends up the side slopes to design flow depth. The earth above the permanent lining should be vegetated or otherwise protected.

Purpose

To provide for safe disposal of runoff from other conservation structures or from natural concentrations of flow, without damage by erosion or flooding, where unlined or grassed waterways would be inadequate.

Where Practice Applies

This practice applies where channel flow velocities exceed those acceptable for a grass lined waterway and/or conditions are unsuitable for the establishment of grass lined waterways. Specific conditions include:

- Concentrated runoff is of such magnitude that a lining is needed to control erosion.
- Steep grades, wetness, prolonged or continuous base flow, seepage, or piping would cause erosion.
- The location is such that use by people, animals, or vehicles preclude use of vegetated waterways.

- High value property or adjacent facilities warrant the extra cost to contain design runoff in limited space.
- Soils are highly erosive or other soil or climate conditions preclude using vegetation.

Planning Considerations

Linings can consist of: rock riprap; non-reinforced, cast-in-place concrete, flagstone mortared in place; or similar permanent linings.

Riprap liners are considered flexible and are usually preferred to rigid liners.

Riprap is less costly, adjusts to unstable foundation conditions, is less expensive to repair, and reduces outlet flow velocity.

Riprap or paved channels can be constructed with grass lined slopes where site conditions warrant.

Volume, velocity, and duration of flow expected are primary considerations for a lined waterway. Other factors include soil characteristics, safety, aesthetics, availability of land, compatibility with land use and surrounding environment, and maintenance requirements. The type of cross section that is selected depends on these factors.

Typical cross sections that can be used include triangular or v-shaped sections, parabolic sections, and trapezoidal sections.

- Triangular sections are used where the volume of flow is relatively small, such as in roadside ditches.
- Parabolic sections are suited for higher flows, but require the use of more land because the channels are generally shallow and wide. When velocities exceed the capability of vegetation, rock riprap can be used as a lining. When there is a continuous base flow in the channel it may be possible to use a combination of rock riprap and vegetation as a lining. The base flow would be carried by the riprap section and the higher flows by the vegetated section; as long as the vegetation is capable of withstanding the velocity.
- A trapezoidal channel is usually used where the flows are relatively large and at higher velocities. Trapezoidal channels usually take up less land than either triangular or parabolic channels.

Regardless of the channel shaped selected, the outlet should be checked to determine if it is stable. It may be necessary to have some type of energy dissipater to prevent scour to the receiving outlet if there is an overflow or if velocities in the contributing channel are higher than the outlet can withstand.

The Wetlands Protection Act requires that for any stream crossing or other work conducted in a wetland resource area, or within 100 feet of a wetland resource area, the proponent file a “Determination of Applicability” or a “Notice of Intent” with the local Conservation Commission.

Design Recommendations

See also Riprap.

Capacity - The minimum capacity should be adequate to carry the peak rate of runoff from a 10-year frequency storm.

Cross Section - The cross section may be triangular, parabolic, or trapezoidal. Monolithic concrete may be rectangular.

Velocity

Rock Riprap Lined Waterways - Rock riprap linings can be designed to withstand high velocities by choosing a stable rock size. Riprap should have a transition material (bedding) placed between the rock and the soil. This transition material can be either a well graded sand-gravel mixture or a geotextile fabric.

Concrete-Lined Waterways - Velocity is usually not a limiting factor in the design of concrete-lined waterways. Keep in mind however that the flow velocity at the outlet must not exceed the allowable velocity for the receiving outlet.

Drainage - Drainage is not a factor when considering using a rock riprap waterway since subsurface water will drain through the transition material and the rock. Concrete lined channels may require drainage to reduce uplift pressure and collect seepage water.

Filters or bedding - Filters or bedding should be used to prevent piping. Filter fabric may be used as the filter. Drains should be used, as required, to reduce uplift pressure and collect water. Weep holes may be used with drains if needed.

Rock Riprap or Flagstone - Stone used for riprap or flagstone should be dense and hard enough to withstand exposure to air, water, freezing and thawing. Flagstone should be flat for ease of placement, and have the strength to resist exposure and breaking.

Construction Recommendations

Outlet must be stable. Stabilize channel inlet points and install needed outlet protection during channel installation.

Remove all trees, brush, stumps, and other objectionable material from channel and spoil areas and dispose of properly.

Construct cross section to the lines and grades shown in plans. Install filter fabric or gravel layer as specified in the plan.

Common Trouble Points

Foundation not excavated deep enough or wide enough

Riprap restricts channel flow, resulting in overflow and erosion.

Side slopes too steep

Causes instability, stone movement and bank failure.

Filter omitted or damaged during stone placement

Causes piping and bank instability.

Riprap poorly graded or stones not placed to form a dense, stable channel lining
Results in stone displacement and erosion of foundation.
Riprap not extended far enough downstream
Causes undercutting. Outlet must be stable.
Riprap not blended to ground surface
Results in gullying along edge of riprap.

Maintenance

Check riprap-lined waterways periodically and after every major storm for scouring below the riprap layer, and to see that the stones have not been dislodged by the flow. Plastic filter cloth, if used, should be completely covered and protected from sunlight.

If the rocks have been displaced or undermined, the damaged areas should be repaired immediately. Woody vegetation should not be allowed to become established in the rock riprap and if present should be removed. Debris should not be allowed to accumulate in the channel.

Give special attention to outlets and points where concentrated flow enters channel. Repair eroded areas promptly.

Concrete-lined waterways should be checked to ensure that there is no undermining of the channel. If scour is occurring at the outlet, appropriate energy dissipation measures should be taken.

If the waterway is below a high sediment-producing area, sediment should be trapped before it enters.

Check for sediment accumulation, piping, bank instability, and scour holes. Sediment and debris deposits should be removed before they reduce the capacity of the channel.

References

Connecticut Council on Soil and Water Conservation, ***Connecticut Guidelines for Soil Erosion and Sediment Control***, Hartford, CT, January, 1985.

Massachusetts Department of Environmental Protection, Office of Watershed Management, Nonpoint Source Program, ***Massachusetts Nonpoint Source Management Manual***, Boston, Massachusetts, June, 1993.

Minnick, E. L., and H. T. Marshall, ***Stormwater Management and Erosion Control for Urban and Developing Areas in New Hampshire***, Rockingham County Conservation District, August 1992.

North Carolina Department of Environment, Health, and Natural Resources, ***Erosion and Sediment Control Field Manual***, Raleigh, NC, February 1991.

Supplementary Information

Rainfall, Runoff, and Land Use Change

Effects of Development

There are two main effects that urbanization has on stormwater. First, an increase in the volume and rate of runoff as development takes place in a watershed. Second, an increased risk of degrading water quality; both surface water and ground water.

Hydrologic Changes

Undeveloped land that is in woods, grass, and/or agriculture, has an ability to absorb rainfall. Rainfall is infiltrated into the soil, used by vegetation, or runs off. Water reaches the earth's surface by rain and snow. Some water is retained on the upper surface of the soil and is either evaporated or transpired into the atmosphere by grass, plants and trees. Some water infiltrates into the soil and becomes groundwater which eventually reaches streams, lakes and oceans.

The remainder of the water falling to the earth becomes runoff and flows into the streams, lakes and oceans as surface flow. Evaporation takes place on these bodies of water and sends the moisture back into the atmosphere as vapor.

When development takes place, vegetation may be removed and replaced with impervious surfaces. These surfaces include roads, streets, parking lots, roof tops, driveways, walks, etc. which reduce the amount of rainfall that can infiltrate into the soil and therefore create more runoff into the surface water system.

In addition to the increase in impervious surfaces, urbanization creates a significant amount of ground surface modification. Natural drainage patterns are modified and runoff is transported via road ditches, storm sewers, drainage swales, and constructed channels. These modifications increase the velocity of the runoff; which in effect decreases the time that it takes for runoff to travel through the watershed. This decreased time creates higher peak discharges.

Increase In Pollution Potential

The largest urban non-point pollution source is sediment and the nutrients and trace metals attached to it. In addition, the runoff from urban areas may carry bacteria, toxic chemicals, hydrocarbons and organic substances.

Sediment is a major pollutant from urban areas. Runoff from construction sites during the urbanization process is the largest source of sediment. Sediment fills road ditches, streams, rivers, lakes and wetlands. A good erosion and sediment control plan can substantially decrease the amount of sediment being produced from urban areas and transported off site.

Nutrients from urban areas are a major concern to surface water quality because of their effects on water bodies. The two major nutrients are nitrogen and phosphorous. Nutrient enrichment can cause an increase in algal growth. Nitrogen consumes large amounts of oxygen in the nitrification process within the water. Both conditions can impair the use of our surface waters for water supply, recreation, and fish and wildlife habitat.

Main sources of nutrients in urban areas include improper use of fertilizers, and organic matter from lawn clippings and leaves. Auto emissions can also contribute phosphorous in areas of heavy traffic.

Trace metals can degrade water quality because of the effect they may have on aquatic life. The most common trace metals found in urban runoff are lead, zinc and copper, however other trace metals such as chromium, nickel and cadmium are frequently found.

Bacteria levels can increase due to urbanization. Fecal coliform bacteria are found in the intestinal tract of warm-blooded animals and can be associated with animal wastes and failed septic systems.

Hydrocarbons from petroleum are commonly found in urban runoff. The hydrocarbons attach to fine sediment and are then transported and deposited throughout the surface water system. Common sources of hydrocarbons are from roads, streets, and parking lots. Other sources include gasoline stations, fuel storage facilities, and improper disposal of motor oil.

Factors affecting surface runoff

Surface runoff is the volume of excess water that runs off a drainage area, or watershed. Peak discharge is the peak rate of runoff from a drainage area for a given rainfall.

A watershed is a drainage area or basin in which all land and water areas drain or flow toward a central collector such as a stream, river, or lake at a lower elevation. The term watershed is synonymous with drainage area; the contributing area, in acres, square miles, or other unit is usually expressed as drainage area.

General

Rainfall is the primary source of water that runs off the surface of small watersheds. The main factors affecting the volume of rainfall that runs off are the kind of soil, type of vegetation and amount of impervious area in the watershed. Factors that affect the rate at which water runs off are watershed topography and shape along with man-made features in a watershed.

Rainfall

The peak discharge from a small watershed is usually caused by intense rainfall. The intensity of rainfall affects the peak discharge more than it does the volume of runoff. The melting of accumulated snow may result in a greater volume of runoff, but usually at a lesser rate than runoff caused by rainfall. The melting of a winter's snow accumulation over a large area may cause major flooding along rivers. Intense rainfall that produces high peak discharges in small watersheds usually does not extend over a large area. Therefore, the same intense rainfall that causes flooding in a small tributary is not likely to cause major flooding in a main stream that drains 10 to 20 square miles.

Hydrologic soil groups

Soils may be classified into four hydrologic soil groups, defined as follows:

Group A soils have low runoff potential and high infiltration rates even when thoroughly wetted. They consist chiefly of sands and gravels that are deep, well drained to excessively drained, and have a high rate of water transmission (greater than 0.30 in/hr).

Group B soils have moderate infiltration rates when thoroughly wetted and consist chiefly of soils that are moderately deep to deep, moderately well drained to well drained, and have moderately fine to moderately coarse textures. These soils have a moderate rate of water transmission (0.15 to 0.30 in/hr).

Group C soils have low infiltration rates when thoroughly wetted and consist chiefly of soils having a layer that impedes downward movement of water and soils of moderately fine to fine texture. These soils have a slow rate of water transmission (0.05 to 0.15 in/hr).

Group D soils have high runoff potential. They have very low infiltration rates when thoroughly wetted and consist chiefly of clay soils with a high swelling potential, soils with a permanent high water table, soils with a claypan or clay layer at or near the surface, and shallow soils over nearly impervious material. These soils have a very low rate of water transmission (0 to 0.05 in/hr).

Cover Type

"Cover type" describes conditions at the soil surface; e.g. vegetation, bare soil, impervious surfaces such as parking areas, roofs, streets, or roads. Cover type affects runoff in several ways. The foliage and its litter maintain the soil's infiltration potential by preventing the impact of the raindrops from sealing the soil surface. Some of the raindrops are retained on the surface of the foliage, increasing their chance of being evaporated back into the atmosphere. Some of the intercepted moisture takes so long to drain from the plant down to the soil that it is Withheld from the initial period of runoff.

Ground cover also allows soil moisture from previous rains to transpire, leaving a greater void in the soil to be filled. Vegetation, including its ground litter, forms numerous barriers along the path of the water flowing over the surface of the land. This increased surface roughness causes water to flow more slowly, lengthening the time of concentration and reducing the peak discharge.

Treatment

Conservation practices reduce erosion and help maintain an "open structure" at the soil surface. This reduces runoff, but the effect diminishes rapidly with increases in storm magnitude.

Check dams, terraces, detention ponds, and similar practices reduce erosion and decrease the amount of runoff by creating small reservoirs. Closed-end level terraces act as storage reservoirs without spillways. Gradient terraces, surface roughening, vegetation increase the distance water must travel or impede its flow - and thereby increase the time of concentration.

Hydrologic conditions

Hydrologic condition indicates the effects of cover type and treatment on infiltration and runoff rates. It is generally estimated from the density of plant and crop residue on the area. Good hydrologic condition indicates that the soil usually has low runoff potential for that specific hydrologic soil group, cover type and treatment. Some factors to consider in estimating the effect of cover on infiltration and runoff are: canopy or density of leaves, amount of year-round cover, percent of residue cover, and the degree of surface roughness.

In most cases, the hydrologic condition of the site affects the volume of runoff more than any other single factor. The hydrologic condition considers the effects of cover type and treatment on infiltration and runoff and is generally estimated from density of plant cover and residue on the ground surface. Good hydrologic condition indicates that the site usually has a lower runoff potential.

A grass cover is "good" if the vegetation covers 75 percent or more of the ground surface. Cover is "poor" if vegetation covers less than 50 percent of the ground surface. Grass cover is evaluated on the basal area of the plant, whereas trees and shrubs are evaluated on the basis of canopy cover.

Topography

The slopes in a watershed have a major effect on the peak discharge at downstream points. Slopes have little effect on how much of the rainfall will run off. As watershed slope increases, velocity increases, time of concentration decreases, and peak discharge increases. An average small watershed is fan-shaped. As the watershed becomes elongated or more rectangular, the flow length increases and the peak discharge decreases.

Potholes may trap a small amount of rain, thus reducing the amount of expected runoff. If potholes and marshland areas make up one-third or less of the total watershed and do not intercept the drainage from the remaining two-thirds, they will not contribute much to the peak discharge. These areas may be excluded from the drainage area for estimating peak discharge. If potholes constitute more than one-third of the total drainage or if they intercept the drainage, a “pond and swamp adjustment factor” can be applied.

Runoff

“Runoff” is the water leaving the watershed during and after a storm. It may be expressed as the average depth of water that would cover the entire watershed. The depth is usually expressed in inches. The volume of runoff is computed by converting depth over the drainage area to volume and is usually expressed in acre-feet.

Hydrologic Methods

Hydrologic methods are well-covered in literature such as Soil Conservation Service (SCS) Technical Release 55, Urban Hydrology for Small Watersheds, other technical documents of various state and federal agencies, commercial publishing houses, and numerous computer programs.

In order to assist designers preparing development plans and local Conservation Commissions reviewing such plans; checklists for reviewing reports prepared using SCS technical releases TR-20, Computer Program for Project Formulation - Hydrology, and TR-55, Urban Hydrology for Small Watersheds, have been included in this section. Natural Resources Conservation Service (formerly Soil Conservation Service) engineers often receive queries about technical details of hydrologic procedures, and a summary of common questions and answers has also been included.

Note: Technical Releases issued prior to November 1994 are referred to as Soil Conservation Service Technical Releases. After November 1994, they are referred to as Natural Resources Conservation Service Technical Releases.

Checklist for Reviewing Reports Using SCS TR-55 Analysis

☑ Watershed map at a scale of 1 inch = 500 feet or larger. Show watershed boundary, sub-area boundaries, and sub-area names or numbers. Show time of concentration, curve number, and drainage area for each sub-area on the map. Contour maps must include some additional area outside the property line boundaries.

☑ Large scale map showing different soils within each sub-area boundary. May also be used to delineate drainage areas. Show the flow route used for calculating time of concentration for each sub-area.

☑ Tabulation sheet or computer printout showing runoff curve number and time of concentration calculations for each sub-area. Drainage areas, hydrologic soils groups, and land use areas should be documented and supported from soils maps or other references.

☑ Tabulation sheet showing calculations and equations used for any storage estimates to design a detention basin.

☑ Narrative explanation and documentation for any sheet flow lengths used that exceed 50 feet.

☑ TR-55 printout showing graphical or tabular peak discharge calculations. include printouts for both pre-development and post-development conditions. The printout showing the design of a detention basin should be included. These printouts should document any claim of zero discharge increase for all required storms.

☑ The written report should state the initial conditions and storm frequencies to be analyzed. Include a summary table showing the pre-development, post-development, and designed system peak discharges for all design frequencies.

☑ Show a sketch of the structure outlet system with elevations and dimensions.

Checklist for Reviewing Reports Using SCS TR-20 Analysis

☑ TR-20 watershed map at a scale of 1 inch = 500 feet or larger. Show sub-area boundaries, cross section locations and numbers, structure locations and numbers, and sub-area names or numbers. Show time of concentration, curve number, and drainage area for each sub-area on the map. Contour maps must include some additional area outside the property line boundaries.

☑ Large scale map showing different soils within each sub-area boundary. May also be used to delineate drainage areas. Show time of concentration calculation path used for each sub-area.

☑ Tabulation sheet or computer printout showing runoff curve number and time of concentration calculations for each sub-area. Drainage areas, hydrologic soils groups, and land use areas should be documented and supported from soils maps or other references.

☑ Tabulation sheet showing calculations and equations used for structure stage, discharge, and storage volumes, and cross-section elevation, discharge, area calculations. Include sketches of structures and cross sections showing elevations and dimensions used in the calculations.

☑ Narrative explanation and documentation for any sheet flow lengths used that exceed 50 feet.

☑ TR-20 printout showing input listing and a minimum output of the summary tables. The minimum required output is listings and summary tables for the pre-development, post-development, and post-development-with-control for all required storms. These printouts should document any claim of zero discharge increase for all required storms.

☑ The written report should state the initial conditions and storm frequencies to be analyzed. Include a summary table showing the pre-development, post-development, and designed system peak discharges for all design frequencies.

Common Questions and Answers About Urban Hydrology for Small Watersheds, TR-55

General

Q. What is the minimum acceptable drainage area for the procedure?
A. The procedure does not have a drainage area limit. It is governed by a minimum time of concentration of 0.1 hours.

Q. What rainfall distribution should be used for Massachusetts?
A. All of Massachusetts is covered by the Type III rainfall distribution. This distribution represents the influence of thunderstorms and tropical storms (e.g. hurricanes) along the coast.

Q. What is the difference between the Type II and Type III rainfall distributions?
A. The Type III distribution is a little less intense than the Type II distribution. The Type III distribution reduces the peak discharges by 34 percent for short time of concentrations of 0.1 hours, by 17 percent for a Tc of 1.0 hours, by 8 percent for a Tc of 3 hours, and approximately the same for time of concentrations of 7 to 10 hours.

Time of Concentration

Q. How do you handle time of concentrations less than 0.1 hours?
A. The procedure has a minimum time of concentration of 0.1 hour. If the computed Tc is less than 0.1 hour, use the minimum value of 0.1 hour. The lower limit is consistent with the available rainfall intensity information from the National Weather Service. The rainfall distribution curve incorporates the high intensity rainfall storm having a 5-minute duration.

Q. What is the acceptable limit for the length of sheet flow?
A. The procedure designates a maximum limit of 300 feet for sheet flow. Considering the definition of sheet flow as flow on a plane surface, a more practical limit in the northeast is 50 to 100 feet.

A good example of sheet flow is flow from the crown of a football field to the edge of the field, where the flow becomes concentrated in a grass swale. In woods the sheet flow length is also short because flow can be diverted by stonewalls, fallen trees, and tree roots. Considering the contributing area represented by sheet flow in proportion to the total drainage area, the travel time for sheet flow should be a small part of the total time of concentration. If the sheet flow length is greater than 10 percent of the total hydraulic length for the watershed or subarea, re-evaluate the sheet flow and travel time calculations.

Q. For sheet flow, should a surface cover of “woods with dense underbrush” be used?
A. This surface cover should be avoided, because the “n” value for this cover type is extrapolated from research data and does not represent typical conditions in the Northeast.

Q. Does shallow concentrated flow need to be used in the time of concentration calculations?
A. The method for shallow concentrated flow is used to calculate the travel time for the transition between sheet flow and open channel flow. If cross section information is available for the shallow concentrated flow segments, they can be treated as open channel flow for calculating travel time.

Q. How can USGS quad sheets be used to calculate time of concentrations?
A. The first segment can be a 50-foot length for sheet flow at the top of the watershed. Shallow concentrated flow will represent segments across parallel contour lines and defined watercourses on the maps. Open channel flow will be used for streams indicated by blue lines on the maps. A field visit of the area should be made to check the flow path and obtain information on the hydraulic characteristics of the channel. This information should include measuring the top width and depth of the channel for bank-full conditions.

Q. Can the upland method (Figure 15.2 in NEH-4) be used to calculate time of concentrations?
A. This method was originally developed for estimating time of concentrations in small rural watersheds. Based on more recent research and analyses, the sheet flow equation in TR-55 has superseded the upland method.

Q. Can other methods be used to calculate time of concentration?
A. The recommended method for calculating time of concentration is the stream hydraulics method. Travel times are calculated based on flow characteristics for each segment in the flow path. Other methods can be used, but they should be checked to see if the results are realistic for the site conditions. The same method should be used when analyzing existing and developed situations.

Hydrographs

Q. Can the hydrograph developed by the Tabular Method be used for detention basin routing?
A. The composite hydrograph developed by the Tabular Method is only a partial hydrograph at the design point based upon rounded time of concentration and travel time values in the tables. The partial hydrograph can be extrapolated to get a total hydrograph for routing by other methods, but this is still an approximation of the entire hydrograph. If hydrographs are needed within the drainage basin or a more precise

hydrograph is needed, another hydrologic method should be used such as TR-20.

Q. Does the Tabular method consider reach routing?
A. The subarea hydrograph is translated downstream based on the travel time for the reach. The method does not consider storage routing in the reach. Floodplain storage in a reach will reduce the peak flow similar to reservoir routing, as well as lag the timing of the peak. If reach storage routing needs to be considered, use the TR-20 hydrology model.

Storage Effects

Q. Can you account for pond and swamp storage within the drainage basin?
A. The Graphical Method has an adjustment factor to account for ponds and swarms spread throughout the basin and not in the time of concentration flow path. In both the Graphical and Tabular Methods, the storage effects within the time of concentration flow path can partially be accounted for by increasing the travel time for the segment, based upon typical pond routings.
The TR-20 hydrology model should be used in order to analyze the actual effects of pond and swamp storage within the basin by routing each storage area.

Q. Can you get a hydrograph with the TR-55 storage routing method?
A. The method just determines the peak outflow or total storage volume required for a detention basin. It is based on average storage and routing effects for many structures and is on the conservative side. If an outflow hydrograph or a more refined storage analysis is needed, the inflow hydrograph needs to be routed by other procedures. The Tabular Method can be used to create an approximate inflow hydrograph. The TR-20 hydrology model can be used to create an inflow hydrograph, conduct storage routings of a detention basin, and calculate the outflow hydrograph.

References

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North Carolina Sediment Control Commission, ***Erosion and Sediment Control Planning and Design Manual***, Raleigh, NC, September, 1988.

U.S. Department of Agriculture, , Washington, DC, Engineering Field Handbook, Chapter 2, ***Estimating Runoff and Peak discharge***.

U.S. Department of Agriculture, Soil Conservation Service, Washington, DC, ***Urban Hydrology for Small Watersheds, Technical Release 55***, June, 1986.

U.S. Department of Agriculture, Soil Conservation Service, Amherst, MA, ***Supplement to the TR-55 Hydrology Procedure***, 1992.

Plants, Vegetation, Soil Covers

Vegetation protects the soil surface from raindrop impact, a major force in dislodging soil particles and moving them downslope. It also shields the soil surface from the scouring effect of overland flow and decreases the erosive capacity of the flowing water by reducing its velocity. Vegetative cover is relatively inexpensive to achieve and tends to be self-healing; it is often the only practical, long-term solution to stabilization and erosion control on most disturbed sites in Massachusetts.

The shielding effect of a plant canopy is augmented by roots and rhizomes that hold the soil, improve its physical condition, and increase the rate of infiltration, further decreasing runoff. Plants also reduce the moisture content of the soil through transpiration, thus increasing its capacity to absorb water.

Planning from the start for vegetative stabilization reduces cost, minimizes maintenance and repair, and makes erosion and sediment control measures more effective and less costly to maintain. Final landscaping is also less costly where soils have not been eroded, slopes are not too steep, and weeds are not allowed to proliferate.

Design projects so that only the area that is totally necessary is disturbed. The existing natural areas provide low-maintenance landscaping, shade, and screening, and soil stability. Large trees increase property value, but must be properly protected during construction.

Besides preventing erosion, healthy vegetative cover provides a stable land surface that absorbs rainfall, cuts down on heat reflectance and dust, restricts weed growth, and complements architecture. It creates a pleasant environment, and an attractive site. Property values can be increased dramatically by small investments in erosion control. Vegetative cover and landscaping represent only a small fraction of total construction costs and contribute greatly to the marketing potential of a development.

Site Considerations

Species selection, establishment methods, and maintenance procedures should be based on site characteristics including soils, slope, aspect, climate, and expected management.

Soils

Many soil characteristics - including texture, organic matter, fertility, acidity, moisture retention, drainage, and slope - influence the selection of plants and the steps required for their establishment.

Nature of Disturbed Soils

Most disturbed sites end up, after grading, with a surface consisting of acid, infertile subsoil materials that lack nutrients necessary for supporting plant growth. Such soils may not be capable of supporting the dense growth necessary to prevent erosion.

Construction activities further decrease soil productivity by increasing compaction, making slopes steeper, and altering drainage patterns. Topsoiling, addition of soil amendments, and special seedbed preparation are generally required. Some native plant species are better suited to these conditions.

Soils Investigation

The vegetative plan should be based on thorough soil sampling and testing in the area of planned construction. Different soils should be sampled separately. Contact the local Conservation District office for suggestions on providers of these services. Test results should include lime and fertilizer recommendations. Fertilizing according to the soil test ensures the most efficient expenditure of money for fertilizer and a minimum of excess fertilizer to pollute streams or groundwater. Soil sampling should begin well in advance of planting because 1 to 6 weeks are required to obtain soil test results.

Information on the soil type is useful in selecting the plants to be used. Native plants growing on similar soils will be good candidates for revegetation.

Wet and dry areas should be checked at the time of maximum wetness and when the dry areas can be differentiated from the wet ones; making it possible to place plants in the microsites for which they are best adapted.

Soil Limitations

Certain soil factors are difficult to modify and can impose severe limitations on plant growth. These include such things as rooting depth, stoniness, texture, and properties related to texture such as organic matter content, and water- and nutrient-holding capacity.

Extremely coarse (gravelly) textures result in droughtiness and nutrient deficiencies. Fine textures, on the other hand, impede infiltration and decrease permeability, thereby increasing the volume of runoff. Light sandy soils may need special treatment with mulches or tackifiers to stabilize them sufficiently to allow plant establishment. Other soils may have a hardpan that limits water and root penetration.

Toxic levels of elements such as aluminum, iron, and manganese are limiting to plant growth. These become less soluble as the pH is raised, however, so that toxicity problems can usually be eliminated by liming.

Soil survey reports may refer to “poor,” “severe,” and “droughty,” soils. These are soils that require special treatment beyond routine tillage and fertilization.

Slope

The steeper the slope, the more essential a vigorous vegetative cover is. Good establishment practices, including seedbed preparation, quality seed, lime, fertilizer, mulching and tacking are critical. The degree of slope may limit the equipment that can be used in seedbed preparation, planting, and maintenance; steep slopes also increase costs.

The severity of past erosion will indicate the degree of mechanical stabilization and slope preparation necessary for plant establishment. Shallow surface erosion will indicate the need for maximum surface plant cover. More deep-seated erosion will indicate the need for a high percentage of deep-rooted species. Relatively small rills and gullies will be smoothed as a matter of course during construction, whereas large gullies may need to be reworked with heavy equipment.

Slope angles steeper than 30-34 percent are difficult to revegetate. Steep slopes should be laid back whenever possible. Vegetation establishment is difficult at best on the tops of cuts. Rounding improves the chances of successful revegetation and minimizes chances of future undercutting.

Aspect

Aspect affects soil temperature and available moisture. South- and west-facing slopes tend to be hotter and drier, and often require special treatment. For example, mulch is essential to retain moisture, and drought-tolerant plant species should be added to the seed mixture. South- and west-facing slopes also may be subject to more frost heaving due to repeated cycles of freezing and thawing.

Temperatures are lower on north- and northeast-facing slopes than on south- and west-facing slopes. Colder temperatures lead to lower evapotranspiration values which result in more available water for plant growth. The effective growing season is reduced somewhat, however; soil temperatures are lower, affecting seed germination, and the possibility of frost damage is greater.

Climate

Climatic differences determine the appropriate plant selections based on such factors as cold-hardiness, tolerance to high temperatures and high humidity, and resistance to disease. Native plant lists give historic information on plants known to have survived in regions over centuries.

Microclimate

Valleys, draws, and low spots will have different microclimates from immediately adjacent higher areas. They will tend to have higher soil moisture because of higher water tables. They will be colder than adjacent higher ground. These conditions will affect plant performance in the same way that they do on slopes of different aspects.

Exposure to winds will vary from site to site in a general area. The winds may occur in either summer or winter or both. Wind increases evapotranspiration and reduces the effective water availability. Summer winds will make plant establishment more difficult, and winter winds may increase winter damage.

Soil pH

Soil pH may limit choices of plant species. Some plants require acid soils, some alkaline, and some are tolerant of a wide range of pH. High soil pH (7.5 and above) or low pH (4.5 or below) may restrict availability of plant nutrients or may make toxic ions available. Extremely low pH levels will increase availability of aluminum, and manganese and other metal ions that are toxic to plants. The pH in surface soils may be satisfactory for plant growth, but highway cuts may expose strata with abnormally high or low pH levels.

Management

When selecting plant species for stabilization, consider post-construction land use and the expected level of maintenance. In every case, future site management is an important factor in plant selection.

Where a neat appearance is desired, use plants that respond well to frequent mowing and other types of intensive maintenance.

At sites where low maintenance is desired, longevity is particularly important. Try to use native species.

Seasonal Considerations

Newly constructed slopes and other unvegetated areas should be seeded and mulched, or sodded, as soon as possible after grading. Where feasible, grading operations should be planned around optimal seeding dates for the particular region. The most effective times for planting perennials generally extend from April through May and from August through September. Outside these dates the probability of failure is higher. Late summer (August 15 - September 30) is the best period to establish grass/legume seedings.

If the time of year is not suitable for seeding permanent cover (perennial species), a temporary cover crop should be planted. Otherwise, the area must be stabilized with gravel or mulch. Temporary seeding of annual species (small grains, Sudangrass, or German millet) often succeeds at times of the year that are unsuitable for seeding permanent (perennial) species,

Dormant seeding can be made from the end of November through March. This type of seeding needs to be adequately protected with mulch, or better yet, erosion control fabric.

Seasonality must be considered when selecting species. Grasses and legumes are usually classified as “warm” or “cool” season in reference to their season of growth. Cool season plants produce most of their growth during the spring and fall and are relatively inactive or dormant during the hot summer months, therefore late summer into early fall is the most dependable time to plant them. Warm season plants greenup late in the spring, grow most actively during the summer, and go dormant at the first frost in fall. Spring and early summer are preferred planting times for warm-season plants.

Plant Species

Species selection should be considered early in the process of preparing the erosion and sedimentation control plan. For practical, economical stabilization and long-term protection of disturbed sites, species selection should be made with care. Many widely occurring plants are inappropriate for soil stabilization because they do not protect the soil effectively, or because they are not quickly and easily established. Plants that are preferred for some sites may be poor choices for others; some can become troublesome pests.

Initial stabilization of most disturbed sites requires grasses and legumes that grow together without gaps. This is true even where part or all of the site is planted to trees or shrubs. In landscape plantings, disturbed soil between trees and shrubs must also be protected either by mulching or by permanent grass-legume mixtures. Mulching alone is an alternative, but it requires continuing maintenance.

Mixtures vs. Single-Species Plantings

Single-species plantings are warranted in many cases, but they are more susceptible than mixtures to damage from disease, insects, and weather extremes. Also, mixtures tend to provide protective cover more quickly. The inclusion of more than one species should always be considered for soil stabilization and erosion control.

Addition of a quick-growing annual provides early protection and facilitates establishment of perennials. More complex mixtures might include a quick-growing annual, one or two legumes, and one or two perennial grasses.

Companion or "Nurse" Crops

The addition of a "nurse" crop (quick-growing annuals added to permanent mixtures) is a sound practice for soil stabilization, particularly on difficult sites - those with steep slopes; poor, stony, erosive soils; late seedings, etc. - or in any situation where the development of permanent cover is likely to be slow. The nurse crop germinates and grows rapidly, holding the soil until the slower growing perennial seedlings become established. Seeding rate of the nurse crop must be limited to avoid crowding, especially under optimum growing conditions.

Legumes: Nitrogen-Fixing Plants

Legumes should be used when practical because of their ability to improve sites by adding nitrogen. They should be inoculated at planting with appropriate bacteria. Commercial inoculants are available for many species. Native species for which no commercial inoculant is available should be inoculated by incorporating soil from native stands in the soils in which transplants are grown, or by topdressing with native soils.

Annuals

Annual plants grow rapidly and then die in one growing season. They are useful for quick, temporary cover or as nurse crops for slower-growing perennials.

Winter rye

Winter rye (grain) is usually superior to other winter annuals (wheat, oats, crimson clover, etc.) both for temporary seeding and as a nurse crop in permanent mixtures. It has more cold hardiness than other annuals and will germinate and grow at lower temperatures. By maturing early, it offers less competition during the late spring period, a critical time in the establishment of perennial species.

Rye grain germinates quickly and is tolerant of poor soils. Including rye grain in fall-seeded mixtures is almost always advantageous, but it is particularly helpful on difficult soils and erodible slopes or when seeding is late. Overly thick stands of rye grain will suppress the growth of perennial seedlings. Limit seeding rates to the suggested level. About 50 pounds per acre is the maximum for this purpose. Where lush growth is expected, that rate should either be cut in half, or rye grain should be eliminated from the mixture.

Annual ryegrass

Annual ryegrass provides dense cover rapidly, but may be more harmful than beneficial in areas that are to be permanently stabilized. Annual ryegrass is highly competitive, and if included in mixtures, it crowds out most other species before it matures in late spring or early summer, leaving little or no lasting cover. It can be effective as a temporary seeding, but if allowed to mature the seed volunteers and seriously interferes with subsequent efforts to establish permanent cover. Winter rye (grain) is preferable in most applications.

German millet

German millet is a fine-stemmed summer annual, useful for temporary seeding, as a nurse crop, and for tacking mulch. It is better adapted to sandy soils than are the Sudangrasses. Normal seeding dates are between the last frost in spring and the middle of August.

Sudangrass

Only the small-stemmed varieties of Sudangrass should be used. Like German millet, Sudangrass is useful for temporary seeding and as a nurse crop, but it is adapted to soils higher in clay content.

Perennials

Perennial plants remain viable over winter and initiate new growth each year. Stands of perennials persist indefinitely under proper management and environmental conditions. They are the principal components of permanent vegetative cover. Wherever possible, use native species for plantings

Native vs. Non-Native Species

In general, if a plant is indigenous to a given area of the country, it is a native. Some define “native” more narrowly, even to a plant indigenous to a given site.

Non-native plant species have been used to control erosion since the dust-bowl days of the 1930s. They are vigorous, establish their dense root systems in the soil, and stabilize bare earth.

These non-native plants, however, can be very competitive. Introduced, invasive plants can cause many more problems than they will solve. They crowd out native species and reduce plant diversity. They are capable of taking over landscapes, resulting in a monoculture. Natural ecosystems are degraded and the site may become vulnerable to disease and pest threats.

Even when non-natives are only a minor component of the seed mix, they tend to outperform and overrun natives for the first few years. Then, over the long term, 10 to 15 years, introduced species may weaken and die out. Native species generally have long-term superiority over non-native species.

Non-natives typically offer two features often lacking with native species; they are readily available and much cheaper than natives. Compared to earthmoving costs on most sites, however, the cost of seed is very small.

In addition to price and availability, project objectives can also affect the decision to plant native or introduced species. For example, an introduced species may be the only seed available that will establish soon enough to protect from a fast-approaching winter and its storms.

Native Species

Native plants evolved under local soil and climatic conditions and are best adapted to sites similar to those on which they grow. They are adapted to annual fluctuations in rainfall and temperatures. Natives often have minimal fungus and insect problems or exist in reasonable balance with such pests. At a proper site, they become established, reproduce, and perform satisfactorily without supplementary irrigation or maintenance. Native plants blend aesthetically with the surrounding vegetation.

Using native plants maintains the genetic integrity of plant populations in the area. Native plants have adapted to an environment; an important consideration in establishing environmentally-sound and low maintenance landscapes.

Native plants are especially adapted to poorer soils and may require no fertilizers or pesticides. Some of them, e.g. sweetfern, refuse to grow well, and sometimes not at all, if given fertilizer. Native plants are also adapted to the soils and require little or no watering.

Retaining native buffers produces great benefits for wildlife. Establishing islands of vegetation offers increased biotic diversity and helps produce wildlife benefits.

Native species maintain natural diversity providing an alternative to boring landscapes which routinely appear around shopping centers, industrial buildings and condominiums. Some people feel that disturbed land should reflect the natural plant systems in place before the site was disturbed.

Native species may be slow to establish, but this is not a significant drawback. Some sort of mulch is usually used anyway to control erosion on newly-seeded disturbed areas. Generally, it takes a year or so before native species can begin protecting the soil, but within two or three years they can provide as much cover as non-natives. Native species are becoming popular for highway embankments, utility corridors, and other development sites.

The availability of native planting stock, seeds or transplants, is sometimes limited because of lack of demand or limited knowledge about propagation methods and cultural requirements. There may be limited numbers of species adapted to artificially altered or disturbed sites. The use of introduced species may be necessary when the numbers of suitable plant species is limited. Increased demand for native plant materials, however, will encourage nursery suppliers to stock them.

Non-Native Species

Other terminology: "Introduced," "Exotic."

The number of introduced species with potential for revegetation of any particular site is usually greater than the number of native species. The commercial availability of introduced species is usually greater because they are the plants of our cultivated landscapes, and more information is usually available about their propagation and cultural requirements.

Introduced plants may sometimes be better adapted to an area than native plants. This may be so because of random chance in evolution or because evolutionary changes in the native plant spectrum have not occurred as rapidly as climatic changes. Introduced plants sometimes have fewer problems than natives because diseases and pests have been "left behind." Introduced species may be more pleasing, aesthetically, than many natives in urbanized areas because they blend with the surroundings.

There are now about 900 alien or introduced plant species in Massachusetts, about a third of the state's flora. In their native habitats, many of these plants were restrained by the pests and diseases that evolved with them over thousands of years. When brought into a new environment, however, they are not bound by natural restraints. The characteristics of disease resistance, fast growth, abundant reproduction, easy propagation, wildlife food production allow them to outcompete and overwhelm native plants.

Native Grasses

Big Bluestem* *Andropogon gerardii*

Big Bluestem is a long-lived perennial, warm-season native grass that has excellent drought resistance. It is being used in critical area seedings where cool season species cannot tolerate the high temperatures or coarse soils. It is selected for the Northeast for its standard durability. It grows from 5 to 7 feet tall and is very leafy.

Big Bluestem is an erosion control plant for sand and gravel pits, mine spoil, and road sides. It is also excellent cover for wildlife.

Seed Big Bluestem in the early spring, taking care to compact the soil after seeding. Seed at 15 to 20 pounds per acre. It is slow to germinate and

establish the first year but will produce fair to good cover by the end of the second year.
Big Bluestem grows well on hot, droughty sites. It tolerates medium to low fertility, acid, sandy, loamy, and clayey soils, has poor shade tolerance and prefers well-drained sites.

Little Bluestem* *Schizachryrium scoparium*
Little Bluestem is a persistent, low maintenance, warm-season bunch type perennial grass. As a native grass, Little Bluestem is almost always incorporated into mixes used to produce longliving native stands. Used as a cover plant on slopes and road banks.
Grows well on either uplands or lowlands. It is drought tolerant and adapted to wide variety of soil types, but is not very shade tolerant. Its russet-red color in fall and winter make it desirable for landscaping.
Height: 1 - 3’
Seedling vigor is weak, and control of competition is necessary. For best results, soil pH should be between 5.5 to 6.5.

Deertongue *Dichanthelium clandestinum*
Deertongue is a native warm-season bunch grass that grows to a height of 1-1/2 to 3 feet. It has broad, short leaves and a strong, fibrous root system. It will tolerate sites with a pH as low as 3.8 and aluminum concentrations which limit growth of other species.
Deertongue is excellent for revegetating acid mine spoil and ground cover for erodible sandy areas, such as road banks, ditch banks, and gravel pits. The seeds are eaten by many species of birds.
Deertongue grows in low-fertility, acid, loamy, and sandy soils. It has excellent drought tolerance, poor shade tolerance, and tolerates moderately well drained soil.
Establish by seeding early in spring. Seed 12 to 15 pounds per acre. It can be seeded with 10 to 15 pounds of tall fescue or perennial ryegrass for quick cover. It will produce complete cover in 2 years.

Eastern Gamagrass* *Tripsacum dactyloides*
A native, warm-season, perennial, tall grass that grows in large clumps from 1 - 4 feet in diameter on stems 3 - 9 feet tall. Regrows vigorously after mowing. Height: 3 - 9’

Indiangrass* *Sorghastrum nutans*
Indiangrass is a native, perennial warm season bunch type grass that grows 3 to 5 feet in height and produces most heavily from July through September.
Indiangrass is excellent for wildlife habitat, critical area seeding and as roadside beautification and erosion control. Indiangrass is winter hardy. It grows best in deep, well-drained soil, but is tolerant of moderately wet soil.

Tumble Lovegrass*_Eragrostis Spectabilis_
Fine-leaved bunch grass; tan, purplish, dainty, feathery seed heads. Grows best in sandy soil. Height: 10 - 12"

Annual Ryegrass _Lolium multiflorum_
Annual Ryegrass is a short lived, annual grass useful for obtaining quick ground cover for lawns, slopes, and mine spoils. It usually germinates in 4 to 7 days, making it very effective for soil erosion. It is adapted to a wide range of soil conditions. Seed in mixtures at a rate of 20 to 30 pounds per acre.

Switchgrass* _Panicum virgatum_
Switchgrass is a medium height to tall perennial grass that grows native in nontidal marshes, stream banks, lake shores, moist woods, and fresh tidal marshes.
Grows under a wide range of soils: low-fertility, acid, sandy, clayey, and loamy soils. Winterhardy, and has excellent heat and drought tolerance, low shade tolerance. Does well on moderately well drained soils. Feathery, open heads; orange-yellow in winter.
Switchgrass is a valuable soil stabilization plant on strip mine spoil, sand dunes, dikes, and other critical areas. It is also suitable for low windbreak plantings in truck crop fields and provides food and excellent nesting and fall and winter cover for wildlife.
Switchgrass requires 1 to 2 years to become totally established. Little or no management is required after establishment.
Height: 4 - 5'
Varieties:
"Blackwell" - reclamation (performs better under low maintenance and wet soils), 4 to 5 feet tall.
"Shelter" - Plant Material Center released variety, wildlife cover, 4 to 6 feet tall. Besides being a good plant for revegetation of surface mine spoil, sand and gravel pits, and steep, sandy roadside cuts, Shelter is an excellent wildlife plant that provides year-round cover and food during the fall and winter. Its stiff stems resist lodging and will recover to an upright position after winter snowstorms.

Canada Wildrye _Elymus canadensis_
A cool season, native grass that prefers moist sites. This perennial bunch grass has very good seedling vigor and early spring growth, which make it easy to establish and cover ground rapidly. (See also Wetland Grasses.)

Riverbank Wild Rye _Elymus riparius_
This rye grows along nontidal shores, wet woods, meadows, prairies and also fresh tidal marshes. With the exception of having a somewhat nodding spike, this perennial grass has very similar characteristics to Virginia Wild Rye. (See also Wetland Grasses.)

Virginia Wildrye *Elymus virginicus*
A cool-season, native grass that tolerates both moist and dry sites, shade and full sun. Medium height perennial. While it can be planted alone, it makes an excellent component in a flood plain mix or a habitat mix. (See also Wetland Grasses.)

Broomsedge *Andropogon virginicus*
Broomsedge is a very hardy perennial which will tolerate both low pH and fertility. It is a clump type grass that will grow to a height of 1 to 3 feet. Mainly found in upland wet areas, an excellent ground cover, and provides feed for game and songbirds.
**Denotes warm-season grass.*

Other Grasses

Kentucky bluegrass
Kentucky bluegrass has higher lime and fertility requirements than some other perennial grasses. Bluegrass spreads by strong rhizomes and, where adapted, is an excellent soil stabilizer, readily filling in damaged spots.
It has undergone intensive breeding activity in recent years, resulting in varieties with more heat tolerance and resistance to hot-weather diseases.

Creeping Red Fescue *Festuca rubra*
Creeping Red Fescue grows in medium fertility, slightly acid, clayey and loamy soils. It has fair drought tolerance, excellent shade tolerance and requires well drained soils. It will produce a complete cover of attractive, uniform sod in one year.
It is a cool season, fine textured, lawn grass that has narrow, bright green leaves. Similar to bluegrass.
It spreads by short underground stems to produce a tight, dense sod for stabilizing road banks and north facing slopes. Above-ground stems have a reddish tint and grow to a height of 18 inches. Red fescue may turn brown in hot, dry summer weather but will recover in the fall.
Red fescue is established by seeding on a firm seed bed in spring or early fall. It is usually used in a mix constituting 25 to 60 percent of the total and seeded at 3 to 5 pounds per thousand square feet. ‘Pennlawn’ is the most popular variety available.

Red Top *Agrostis alba*
Redtop is a tough, cool-season perennial grass tolerant of infertile, droughty, somewhat acid soils.
Red Top will provide quick cover for critical areas such as grassed waterways, road banks, diversions, and strip mine spoils. Other uses include erosion control, and temporary grass in turf seedings. It can be a useful component of mixtures on dry, stony slopes.
It is a fast-starting, sod-forming grass that is about 18 inches tall at maturity. It will produce effective ground cover the first year. Because it is fast starting and tolerates cold temperatures and poorly drained soils, red top is widely used as a component in mixtures planted on disturbed sites

in Northeast.
Red Top grows in clayey, loamy, and sandy soils. It has poor shade tolerance.

Perennial Ryegrass *Lolium perenne*
Perennial Ryegrass is a fast growing, short term grass used for soil stabilization and improvement and lawns. Rapid growth rate is the primary conservation value, producing complete cover in a few months.
It grows in medium fertility, acid, clayey and loamy soils. It has fair drought tolerance, poor shade tolerance and will tolerate somewhat poorly drained soil. It grows to a height of 1 to 2 feet. Many long, narrow leaves extend from the base of the plant.
Oftentimes, seeding mixtures containing red fescue, redtop, Canada bluegrass, or perennial ryegrass are used; as they provide good short term erosion protection, but will allow indigenous plants to eventually naturalize the site.
When used in mixes, ryegrass should not exceed 20% of the mix. The turf varieties are longer lived and include ‘Manhattan II,’ ‘Pennant’ and ‘Pennfine.’

Native Legumes

Roundhead lespedeza *Lespedeza capita*
Roundhead lespedeza is common on sand dunes, dry fields, sandy woods, and roadsides. It is important for soil stabilization. It flowers from June to September. The foliage is eaten by deer and turkeys. Seeds are consumed by upland birds and rodents.
Roundhead lespedeza seed is commercially available. The seed should be scarified to assure high rates of germination. Life span: perennial.

Panicled tickclover *Desmodium paniculatum*
Panicled tickclover is infrequent to locally common in dry woods, especially if the soil is rocky or sandy. It occasionally is found on roadsides. It flowers from July to September. It is consumed by domestic livestock and deer while it is immature. Rodents and birds utilize the seeds.
Seed is not commercially available. Panicled tickclover has no value for landscaping or erosion control. Life span: perennial.

Canada tickclover *Desmodium canadense*
Canada tickclover is infrequent to common in prairies and thickets and along rivers and roads. It is most common in sandy soil. It flowers from July to September. Foliage is eaten by deer and rabbits. Many kinds of rodents and birds eat the seeds.
Canada tickclover is poor for erosion control. It has no value for landscaping. Life span: perennial.

Yellow wildindigo *Baptisia tinctoria*
Yellow wildindigo is scattered to common in open woods and clearings. It flowers from late May through July. Life span: perennial.
Seed is seldom commercially available. Most seed is destroyed in the legume by weevils. Germination may be improved by scarification and stratification. It is an attractive landscape plant.
Caution must be taken, because it may be poisonous to humans.

Groundnut *Apios americana*
Groundnut is infrequent to locally common in moist soils of ravines, pond and stream banks, and thickets. Life span: perennial.
Seeds are eaten by upland game birds and song birds. Tubers are eaten by mice, rabbits, and squirrels.
Seed is not commercially available. The plant has no potential for landscaping, although it holds promise as a tangle vine for erosion control.

Beach pea *Lathyrus japonicus*
Native to coastal Massachusetts. Adapted to beach/dune sites. Life span: perennial.
Seeded in moist, inter-dune areas.

Bush clover *Lespidesa capitata*
Bush clover may be used in locations where Sericea Lespedeza would previously have been recommended.

Native Ground Covers

Wintergreen *Gaugtheria paceumbens*
6" (Height) x 3’ (Spread)
Acid, average/dry soil. Partial shade. Evergreen, reddish in winter, pinkish-white flowers, red berries.

Bearberry *Artostaphylus uva-ursi*
9" x 3’
Sandy soil. Full sun to partial shade. Evergreen, bronze in fall, urn-shaped flowers, red berries, sturdy and reliable.

Cranberry *Vaccinium macrocarpon*
4" x 3’
Cool, moist soil. Full sun. Evergreen, dense, glossy, red edible fruit.

Bunchberry *Cornus Canadensis*
6"
Moist, acid soil. Partial/full shade. Excellent under pines, broad-leaved evergreens, lovely fruit, whorled leaves, beautiful.

Trailing arbutus *Epigaea repens*
5" x 2'
Acid, sandy soil with oak leave/pine needle mulch. Evergreen; dainty, fragrant flowers, does not tolerate disturbance. State flower of Massachusetts.

Virginia creeper *Parthenocissus quinequefolia*
35'
Vine/ground cover. Tolerant as to soil. Sun/shade. Excellent low-maintenance cover, does not need support, red in fall, blue berries.

Coastal Dune Vegetation

Revegetation of construction sites requires special attention to selection of plant species. In the foredune area there are only a few plants that tolerate the stresses of the beach environment. They must be able to survive salt spray, sand blasting, burial by sand, saltwater flooding, drought, heat, and low nutrient supply.

'Cape'American beachgrass

American beachgrass is a cool-season perennial dune grass; for dune building and as a stabilizer in the foredune zone. Easy to propagate, it establishes and grows rapidly, and is readily available from commercial nurseries.

It is an excellent sand trapper capable of growing upward with four feet of accumulating sand in one season. New plantings are usually effective at trapping wind-blown sand by the middle of the first growing season. Beachgrass is also a good plant for interior dune zones as well as other droughty, sandy sites inland.

American beachgrass is extremely valuable for initial stabilization and dune building in disturbed areas. It is severely affected by heat and drought and tends to deteriorate and die behind frontal dunes as the sand supply declines.

It is also susceptible to a fungal disease (Marasmius blight) and a soft scale insect (Eriococcus carolinae). Beachgrass plantings should, therefore, be reinforced with plantings of woody species such as beach plum or barberry. Interior dune areas are candidates for a wider variety of coastal woody shrubs.

Saltmeadow cordgrass

A warm-season perennial useful for transplanting on low areas subject to saltwater flooding. It is a heavy seed producer and is often the first plant on moist sand flats. It collects and accumulates blowing sand, creating an environment suitable for dune plants.

Saltmeadow cordgrass is easy to transplant on moist sites but does not survive on dry dunes. Plants should be dug from young, open stands. Survival of transplants from older, thick stands is poor. Nursery production from seed is relatively easy, and the pot-grown seedlings transplant well. Propagation by seed is possible, but the percentage of viable seed varies.

Beach plum

A shrub of the New England coastal areas, of special interest for its edible fruit. It grows well in sandy, dry, windswept sites, and produces a profusion of white flowers in early May. Beach Plum grows to about 6 feet in height and makes an excellent massed seaside planting or a hedge to prevent erosion because it can tolerate salt spray. Nursery grown plants are recommended, as transplanting from the wild is not often successful. Produces flowers and fruit in 3 to 4 years; matures in 7 to 8 years.

Beach Plum requires cross-pollination to insure fruit production so it is necessary to have more than one plant if plums are desired. Beach plum can be grown in areas other than coastal dunes. Grows in medium-fertility, acid, loamy, and sandy soils; excellent drought tolerance; fair shade tolerance; tolerates moderately well-drained soil.

Bayberry

Bayberry is a semi-evergreen shrub that grows to a height of 6 to 8 feet. Ideal for sunny, coastal sites. Grows in low-fertility, acid, clayey, loamy, and sandy soils; excellent drought tolerance, poor shade tolerance; tolerates moderately well-drained soil. Versatile for landscaping and revegetating, sand dunes and inland areas; berries provide food for birds. It can also help stabilize dry slopes prone to erosion.

Produces fruit in 3 to 4 years; matures in 7 to 8 years. Fruit appears only where both male and female shrubs are planted in the same area. Roots fix nitrogen, which helps bayberry grow in low-fertility soil. Establish by planting bare-root or container-grown seedlings 2 years old.

Bayberry does best in open sites. It can be rejuvenated by cutting it back hard, which stimulates underground lateral stem growth. Stems root at the nodes where new leaves form, and new plants can be established by pinning down a prostrate stem node tightly against the soil.

Rugosa Rose

Rugosa Rose produces large bushy masses of greenery topped by red and white blossoms from soil that is little more than loose sand. Spreading and sprawling, its six-foot branches covered with spines, the plant is a formidable barrier that deters trampling feet and anchors dunes.

It is useful for roadside and dunes, replacing plants which could not tolerate the abuse of pedestrian traffic.

Intertidal Vegetation

In saltwater areas, smooth cordgrass is transplanted in the intertidal zone from mean sea level to mean high water, and saltmeadow cordgrass from mean high water to the storm tide level. In brackish water areas (10 parts per thousand or less of soluble salts), giant cordgrass may be used in the intertidal zone. Greenhouse-grown seedlings of these plants can be obtained from commercial sources, but usually only on special order. Transplants may be dug from young, open natural stands of smooth and saltmeadow cordgrass.

Smooth cordgrass

Smooth cordgrass is the dominant plant in the regularly flooded intertidal zone of saltwater estuaries along the Atlantic and Gulf Coast of North America. It is adapted to anaerobic, saline soils that may be clayey, sandy, or organic. It will tolerate salinities of 35 parts per thousand (ppt) but grows best from 10 to 20 ppt.

Plant height varies from 1 to 7 ft depending on environmental conditions and nutrient supply. It produces a dense root and rhizome mat that helps prevent soil movement. Transplants can be obtained by digging from new, open stands of the grass or may be grown from seed in pots. Seed are collected in September and stored, covered with seawater, and refrigerated. The plants and seedlings grow rapidly when transplanted on favorable sites.

Saltmeadow cordgrass

A fine-leaved grass, 1 to 3 ft in height, that grows just above the mean high tide line in regularly flooded marshes, and throughout irregularly flooded marshes. It can be propagated in the same way as smooth cordgrass except that seed may be stored dry under refrigeration. A stand of saltmeadow cordgrass provides good protection from storm wave erosion.

Giant cordgrass

Grows in brackish, irregularly-flooded areas. Stems are thicker and taller than in the other cordgrasses, growing to a height of 9 to 10 feet. Seedlings are easy to produce in pots and these can be successfully transplanted, but survival of plants dug from existing stands is poor.

Salt grass *Distichlis spicata*

Salt grass is another appropriate plant for intertidal zones.

Native Shrubs

Bayberry *Myrica pensylvanica*
9' (Height) x 9' (Spread)
Sandy/clay soils. Full sun to half-shade. Excellent for massing, borders, foundation plantings.

Mountain Laurel *Kalmia latifolia*
11' x 11'
Acid, moist, well-drained soil. Sun/shade. Evergreen, magnificent in flower, exquisite in mass.

Common Buttonbush *Cephalanthus occidentalis*
9' x 16'
Moist soil. Sun. Loose in appearance; white, fragrant flowers; best for naturalizing in wet areas.

Pinxterbloom Azalea *Rhododendron nudiflorum*
9' x 9'
Dry, sandy, acid soil. Bright green foliage, yellow in fall, fragrant light-pink flowers, deciduous.

Roseshell Azalea *Rhododendron noxeum*
9' x 9'
Moist/dry soil. Deciduous, much-branched, bright pink flowers with clove-like scent.

American Elder *Sambucus canadensis*
9'x 6'
Moist/dry soil. White profuse flowers, edible fruit, good for naturalizing.

Hardhack Spirea *Spiraea tomentosa*
5' x 5'
Moist soil. Sun. Pink spike-like flowers, thicket of wand-like stems.

Canada Yew *Taxus canadensis*
5'x 7'
Moist, sandy soil. Needs winter shade. Evergreen, hardy; suitable for underplanting in cool, shaded situations.

Lowbush Blueberry *Vaccinium augustifolium*
2'x 2'
Dry, acid soil. Sun/partial shade. White flowers, sweet berry, lustrous blue-green foliage.

Highbush Blueberry *Vaccinium corymbosum*
9' x 10'
Dry, acid soil. Sun/partial shade. Excellent fall color, rounded, compact, edible fruit, white flower.

American Cranberrybush *Viburnum Viburnum milobum*
9' X 9'
Well-drained, moist soil. Sun/partial shade. Informal hedges; excellent flower, fruit, foliage.

Summersweet Clethra *Clethra alnifolia*
6' x 5'
Moist, acid soil. Sun/shade. White fragrant flowers, handsome foliage, pest-free.

Grey Dogwood *Cornus racerosa*
12' x 12'
Moist, well-drained soil. Sun/shade. (***See also Wetland Shrubs***.)

Beaked Filbert *Corylus cornuta*
6'x 6'
Well-drained, loamy soil. Sun/light shade. Interesting beaked fruits, refined, edible fruit.

Common Winterberry *Ilex verticillata*
8'x 8'
Moist, acid soil. Sun/partial shade. Shrub borders, massing waterside planting, male and female required for fruit, red fruit framed by snow. (***See also Wetland Shrubs***.)

Common Juniper *Juniperus communis*
7' x 10"
Dry soil. Sun. Useful for undergrowth and naturalized plantings, extremely hardy, evergreen.

Common Spicebush *Lindera benzdin*
9' x 9'
Moist, well-drained soil. Sun/half shade. Splendid plant in flower and fall color, ornamental fruit. (***See also Wetland Shrubs***.)

Bush Cinquefoil *Potentilla pruticosa*
3' x 3'
Moist, well-drained soil. Sun/partial shade. Low hedge, perennial border, yellow flowers, graceful appearance.

Blackhaw Viburnum *Viburnum prunifolium*
13'x 10'
Tolerant as to soil. Sun/shade. Massing, shrub border, stiffly branched, red in fall, white flowers.

Rugosa Rose (naturalized) *Rosa rugosa*
5'x 5'
Well-drained soil. Sun. Beautiful in foliage, flower, fruit, hedging, low maintenance, hardy, fragrant flowers.

Native Trees

Red maple *Acer rubrum*
50' (Height) x 50' (Spread)
Acid, moist soil. One of first trees to color in fall, dazzling fall color.

Sugar maple *Acer saccharum*
70' x 50'
Well-drained, slightly acid soil. Beautiful fall color, pleasing growth habit.

Shadblow *Amelanchier canadensis*
20' x 20'
Average/moist soil. White flowers, edible sweet fruit, yellow in fall.

Sweet birch *Betula lenta*
50'x 40'
Rich, moist, well-drained soil. Reddish-brown bark, best of birches for fall color.

Paper birch *Betula papyrifera*
60'x 30'
Well-drained, acid soil. Full sun. Handsome for bark and fall color, splendid in winter with evergreens.

Common choke cherry *Prunus virginiana*
25' x 22'
Well-drained soil. Sun to partial shade. Rounded crown, red/purple edible fruit, white fragrant flowers.

White oak *Quercus alba*
75' x 75'
Moist, well-drained acid soil. Sun. Majestic tree for large areas.

Northern red oak *Quercus borealis*
75'x 60'
Acid, well-drained soil. Shade tolerant. High wildlife value, ascending branches, globular.

Rosebay rhododendron *Rhododendron maximum*
20'x 10'
Moist, acid soil. Shade. Loose, open habit; large, evergreen leaves; rose flowers.

Pussy willow *Salix discolor*
25' x 6'
Moist soil. Sun. Multiple trunks, leggy, high wildlife value.

Canada hemlock *Tsula canadensis*
50' x 30'
Moist, well-drained, acid soil. Sun/shade. Evergreen hedges, graceful, does not tolerate wind or drought.

Nannyberry viburnum *Viburnum lentago*
20' x 15'
Moist/dry soil. Sun/shade. Durable naturalizing or shrub borders, white flowers, handsome fruit, good winter food for birds. (***See also Wetland Trees.***)

Shagbark hickory *Carya ovata*
70'x 35'
Adaptable to wide range of soils. Edible nuts, "shaggy" bark, picturesque. Use chips for barbecues.

Pagoda dogwood *Cornus alternifolia*
20'x 30'
Moist, acid, well-drained soil. Partially shaded. Horizontal, low-branched, excellent textural effects.

Flowering dogwood *Cornus florida*
40' x 40'
Acid, well-drained soil. Four-season character; flower, foliage, fruit, winter habit.

Witchhazel *Hamamelis virginiana*
25' x 20'
Moist soil. Sun/shade. Shrub border, fragrant flowers, yellow in fall. (***See also Wetland Trees***.)

Eastern red cedar *Juniperus virginiana*
45' x 14'
Moist soil. Sun. Windbreaks, hedges, reddish-brown bark, evergreen.

Eastern larch *Larix laricina*
60' x 25'
Moist, well-drained acid soil. Sun. Excellent in groves, horizontal, drooping branches, deciduous.

Eastern white pine *Pinus strobus*
70'x 30'
Tolerant as to soil. Sun/some shade. Handsome, beautiful hedge, graceful, plume-like branches.

Quaking aspen *Populus tremuloides*
40' x 25'
Tolerant as to soil. Narrow leaves flutter in breeze, yellow in fall.

Black cherry *Prunus serotina*
50'x 25'
Moist/dry soil. Sun. Oval-headed; lustrous, dark-green leaves, edible fruit.

Native Wetland Herbs and Grasses

Sweet flag *Acorus calamus*
Sweet Flag is a perennial herb usually 1 to 4 feet tall. It flowers from May to August and has a very pleasant aroma. It grows in shallow waters, nontidal marshes, wet meadows, and fresh tidal marshes.

Swamp Aster *Aster puniceus*
Swamp Aster is a popular wetland perennial herb. It differs from New England Aster in that it often has hairy, purplish stems. It blooms from July to October sporting a bluish, daisy-like flower. The Swamp Aster, also known as the Red Stalk or Purple Stemmed Aster, prefers very moist, swampy areas.

Nodding Bur Marigold *Bidens cernua*
Bur Marigold is an annual herb that reaches up to 3-1/2 feet tall. Its large, yellow, daisy-like flowers, which contain six to eight "petals," will nod as their maturity increases from July into October. It grows in freshwater marshes and along stream banks.

Beggar Ticks *Bidens frondosa*
Beggar-Ticks, also known to many as the Stick-Tight, is an annual herb reaching up to 4 feet. It produces small yellow to orange flowers from June to October. It is found in many wet areas including ditches, pastures, and wet meadows and fields.

Fringed Sedge *Carex crinita*
Fringed Sedge is a perennial grass like plant growing up to 4-1/2 feet high. It flowers from May through June and grows in fresh water marshes, wet meadows, forested wetlands, pond borders, and ditches.

Lurid Sedge *Carex lurida*
This sedge will reach up to 3-1/2 feet tall. It flowers from June into October and grows in freshwater marshes, wet meadows, forested wetlands, ditches, and pond borders.

Fox Sedge *Carex vulpinoidea*
Fox Sedge is very hardy, an ideal pioneer plant when establishing new wetlands. It is a perennial grass like plant reaching up to 3-1/2 feet tall. It flowers from June through August. It grows in fresh water marshes, wet meadows, and other wet places.

Grass-Leaved Goldenrod *Solidago graminifolia*
Grass Leaved Goldenrod is a perennial herb growing up to 4 feet tall. Small yellow flowers appear on the top of the stem from July through October. It grows in nontidal marshes and meadows, various open, moist or dry inland habitats and brackish tidal marshes.

Hop Sedge *Carex lupulina*
These sedges are perennial grasslike plants very common to wetlands. They add beauty as well as seed for ducks and other wildlife. They reach heights between 1- ½ to 3 feet tall and bloom from May to October. They grow well in open woodlands, seasonally flooded areas, standing water, and saturated soils.

Riverbank Wild Rye *Elymus riparius*
This rye grows along nontidal shores, wet woods, meadows, prairies and also fresh tidal marshes. With the exception of having a somewhat nodding spike, this perennial grass has very similar characteristics to Virginia Wild Rye.

Virginia Wild Rye *Elumus virginicus*
Virginia Wild Rye is an excellent pioneer species to use when establishing a new wetland. A cool season perennial, it is good for wildlife cover and food and grows up to 5 feet tall. It is also good for forage. It is found in flood plains, thickets, along road sides, and many other wet areas. It is shade and drought tolerant and can handle wet areas better than Riverbank Wild Rye.

Canada Wild Rye *Elymus canadensis*
Canada Wild Rye is a cool season perennial bunch grass. It is good for wildlife food and cover, growing up to 6 feet tall. It is also good for forage. It grows in dry or moist soils and is drought tolerant.
Joe-Pye Weed (Spotted Flat-Topped) *Eupatoriadelphus maculatus or Eupatorium maculatum*
A very common wetland plant in the northeastern United States. It grows in forested wetlands, saturated fields or meadows, and in shrub swamps. It can be identified by its purple or purplespotted stems and a flat-topped inflorescence with small pinkish or purplish flowers that bloom from July through September.

Boneset *Eupatorium perfoliatum*
Boneset is a perennial herb reaching up to 5 feet high. It flowers in late July through October. Nontidal and fresh tidal marshes, wet meadows, shrub swamps, low woods, shores and other moist areas.

Arrow Arum *Peltandra virginica*
Arrow Arum is a fleshy perennial herb that grows up to 2 feet tall. Inconspicuous flowers on a spike enclosed within a pointed leaf-like structure will appear from May through July. Arrow Arum grows in shallow waters of ponds, lakes, swamps, and marshes.

Pennsylvania Smartweed *Polygonum pennsylvanicum*
Smartweed is an annual herb reaching a height of 6-1/2 feet tall. It grows well in fresh water marshes and wet fields and meadows. Its pink or purple flowers are very small and are arranged in dense clusters.

Blue Flag *Iris versicolor*
A member of the Iris family, Blue Flag is an eye-catching wetland perennial herb that grows in many wet areas including nontidal and tidal marshes, wet meadows, and shores. A blue flower can be seen on the Blue Flag from May through July.

Rattle Snake Grass *Glyceria canadensis*
This perennial grass grows to a height up to 3-1/2 feet tall. It blooms from June through August in forested wetlands, wet meadows, and bogs.

Fowl Manna Grass *Glyceria striata*
A perennial grass that will reach 4 feet in height. It prefers freshwater marshes, open forested wetlands, and other saturated soils. It blooms from June on into September.

Soft Rush *Juncus effusus*
Soft Rush is a perennial grass-like plant that grows up to 3-1/2 feet tall. It flowers from July into September. It grows in nontidal marshes, wet meadows, shrub swamps, wet pastures, and fresh tidal marshes.

Sensitive Fern *Onoclea sensibilis*
Sensitive Fern grows up to 3-1/2 feet tall. It flowers from June into October. It grows in nontidal marshes, meadows, forested wetlands, and fresh tidal marshes, and moist woodlands.

Rice Cutgrass *Leersia oryzoides*
Rice Cutgrass is a medium height to tall perennial grass growing up to 5 feet high. It flowers from June into October. It grows in nontidal marshes, wet meadows, ditches, muddy shores, and fresh tidal marshes.

Wool Grass *Scirpus cyperinus*
Wool Grass is a medium height to tall perennial grass like plant that grows up to 6-1/2 feet high. It flowers from August through September. It grows in nontidal marshes, wet meadows, swamps, and fresh tidal marshes.

Soft-Stemmed Bulrush *Scirpus validus*
This perennial herb grows to a height of up to 10 feet. It flowers from June into September. It grows in inland shallow waters, shores, nontidal marshes, and brackish and fresh tidal marshes.

Canada Goldenrod *Solidago canadensis*
Canada Goldenrod is a medium to tall perennial herb, sporting small yellow flowers in August through October. It grows well along stream banks, and in upland wet areas.

Eastern Bur-Weed *Sparganium americanum*
Eastern Bur-Weed is a perennial growing up to 3-1/2 feet tall. It flowers from May through August. It grows in muddy shores, shallow waters and nontidal marshes.

Prairie Cordgrass *Spartina pectinata*
Prairie Cordgrass is a native perennial that grows from 2 to 7 feet tall. It flowers from July through September and grows in wet spots.

Narrow-Leaved Cattail *Typha angustifolia*
Narrow-Leaved Cattail provides food and shelter for wildlife and is used to control erosion. It has narrow leaves (1/2" wide) and reaches up to 6 feet tall.

Cattail *Typha latifolia*
The Cattail is a perennial herb growing to 10 feet high. It flowers from May through July. It grows in nontidal marshes, ponds, ditches, and fresh tidal marshes.

Blue Vervain *Verbena hastata*
Blue Vervain is a perennial herb that grows up to 5 feet tall. The flowers are bluish to violet and are borne on several dense spikes. Its blooms begin in June and continue through October. It does well in nontidal marshes, wet meadows, open shrub swamps, and moist fields.

Turtlehead *Chelone glabra*
Turtlehead is a perennial herb growing up to 3 feet tall. The flowers, which bloom from July to September, resemble turtle heads as the petals are two-lipped and tubular. It can be found growing along stream banks, forested wetlands, swamps and fresh water marshes.

Native Wetland Shrubs and Trees

Red Osier Dogwood *Cornus stolonifera*
Has red stems, green leaves, and white fruit. Its ability to spread by layering and its tolerance of wet soils makes it an excellent choice for stream bank erosion control. It is also a useful upland plant, providing food and cover for wildlife and color for shrub borders and landscaping. Grows in medium-fertility, slightly acid, clayey, loamy, and sandy soils. It has moderate shade tolerance and poor drought tolerance.
When planting along stream banks, plant at the waters edge, using rooted cuttings or fresh hardwood unrooted cuttings that are at least 9 to 12 inches long and leaving 2 inches of the stem above ground. Spreads by layering where stems contact the ground. It is moderately fast growing, reaching a height of 6 to 10 feet.

Button bush *Cephalanthus occidentalis*
Button Bush is a broad leaved, deciduous, tall shrub or small tree growing to 33 feet high. Its flowers are white and appear from May though June. It grows in nontidal and fresh tidal marshes and shrub swamps, forested wetlands, and borders of streams, lakes and ponds.

Grey Dogwood *Cornus racemosa*
Grey Dogwood is a shrub similar to Silky Dogwood, but possesses grey twigs and white berries. It grows in medium fertility, acid, clayey, loamy and sandy soils. Unlike Silky Dogwood it requires well-drained soil. It is best adapted along stream banks, in forested wetlands and shrub wetlands. It can be established by seed or unrooted cuttings.

Silky dogwood *Cornus amomum*
Silky Dogwood is a broad leaved deciduous shrub that grows to a height of 9 to 12 feet. White flowers and blue or white berries remain until late summer or early fall. It is used for stabilizing lower slopes of stream banks. It also provides food and cover for game birds, song birds, rabbits, raccoon, and other wildlife.
To establish on stream banks plant Silky Dogwood seedlings, rooted cuttings or unrooted cuttings 2 feet apart or broadcast seed. Silky Dogwood provides effective stream bank protection in 3 to 5 years and also produces fruit at this age. Silky Dogwood grows in forested wetlands, shrub wetlands, stream banks, and moist woods. It grows in medium fertility, acid, clayey, loamy, and sandy soils. It has fair drought tolerance, fair shade tolerance and tolerates poorly drained soil.

Witch Hazel *Hamamelis virginiana*
Witch Hazel is a broad-leaved deciduous shrub or low tree up to 30 feet tall. It flowers from September into November. It grows in seasonally flooded swamps and forested wetlands, and tidal swamps.

Common Winterberry *Ilex verticillata*
Winterberry is a broad leaved, deciduous shrub growing up to 16 feet tall. It flowers from May through July. It grows in seasonally flooded shrub swamps and forested wetlands. Showy red berries remain on the plant until spring.

Spicebush *Lindera benzoin*
Spicebush is a broad leaved, deciduous shrub growing up to 16 feet tall. It flowers from March through July. It grows in nontidal marshes, ponds, ditches and fresh tidal woodlands.

Swamp Rose *Rosa palustris*
Swamp Rose is a broad-leaved, deciduous thorny shrub growing up to 7 feet tall. It blooms pink five-petalled flowers from May through July. It grows in upland fields, thickets, and woods, and forested wetlands.

Black Willow *Salix nigra*
A broad-leaved deciduous shrub or tree that can reach a height of 70 feet tall or more. It grows well in nontidal forested wetlands, fresh tidal marshes, tidal swamps, and wet meadows. Identifying characteristics of the Black Willow is its brownish or blackish deeply grooved bark and its narrow leaves.

Common Elderberry *Sambucus canadensis*
Elderberry is a broad leaved deciduous shrub growing up to 12 feet tall. It flowers from June through July. It grows in nontidal and fresh tidal marshes and swamps, meadows, old fields, moist woods, and along road sides.

Arrowwood Viburnum *Viburnum dentatum*
Arrowwood is a broad leaved deciduous shrub growing up to 15 feet tall. It flowers from May through July. It grows in nontidal and fresh tidal marshes, shrub swamps, and forested wetlands. It also does well in moist woods, and various drier sites.

Nannyberry or Wild Raisin *Viburnum lentago*
Nannyberry is a broad leaved deciduous shrub or small tree growing up to 27 feet tall. It has long, pointed leaves with winged stalks. It flowers from April into May and produces berries in the fall that are eaten by wildlife. It grows in forested wetlands, open upland woods and thickets, fence rows and road sides.

Northern or Smooth Arrowwood *Viburnum recognitum*
Arrowwood is a broad leaved deciduous shrub growing up to 15 feet tall. It flowers from May through July. It grows in nontidal and fresh marshes, shrub swamps, forested wetlands, moist woods and various drier sites.

American Cranberrybush *Viburnum trilobum*
This shrub provides winter food for grouse, songbirds, and squirrels and is useful for hedges and borders. It grows in medium-fertility, acid, clayey, loamy and sandy soils. It has poor drought tolerance, fair shade tolerance and tolerates poorly drained soil.

Establishing Vegetation

Site Preparation

The soil on a disturbed site must be modified to provide an optimum environment for germination and growth. Addition of topsoil, soil amendments, and tillage are used to prepare a good seedbed. At planting the soil must be loose enough for water infiltration and root penetration, but firm enough to retain moisture for seedling growth. Tillage generally involves disking, harrowing, raking, or similar method. Lime and fertilizer should be incorporated during tillage.

Topsoiling

The surface layer of an undisturbed soil is often enriched in organic matter and has physical, chemical, and biological properties that make it a desirable planting and growth medium. Topsoil should be stripped off prior to construction and stockpiled for use in final revegetation of the site.

Topsoiling may not be required for the establishment of less demanding, lower maintenance plants, but it is essential on sites having critically shallow soils or soils with other severe limitations. It is also essential for establishing fine turf and ornamentals.

Soil Amendments

Liming

Liming is almost always required on disturbed sites to decrease the acidity (raise pH), reduce exchangeable aluminum, and supply calcium and magnesium. Even on the best soils, some fertilizer is required. Suitable rates and types of soil amendments should be determined through soil tests. Limestone and fertilizer should be applied uniformly during seedbed preparation and mixed well with the top 4 to 6 inches of soil.

Organic amendments

Organic amendments, in addition to lime and fertilizer, may improve soil tilth, structure, and water-holding capacity—all of which are highly beneficial to seedlings establishment and growth.

Some amendments also provide nutrients. Examples of useful organic amendments include well-rotted animal manure and bedding, crop residue, peat, and compost.

Organic amendments are particularly useful where topsoil is absent, where soils are excessively drained, and where soils are high in clay. The application of several inches of topsoil usually eliminates the need for organic amendments.

Surface Roughening

A rough surface is especially important to seeding sloped areas. Contour depressions and loose surface soil help retain lime, fertilizer, and seed. A rough surface also reduces runoff velocity and increases infiltration.

Permanent Cover

A permanent type of vegetation should be established as soon as possible: to reduce damages from sediment and runoff to downstream areas; and to avoid severe erosion on the site itself.

Vegetation may be in the form of grass-type growth by seeding or sodding, or it may be trees or shrubs, or a combination of these. Establishing this cover may require the use of supplemental materials, such as mulch or jute netting.

Planting Methods

Seeding is the fastest and most economical method that can be used with most species. However, some grasses do not produce seed and must be established by planting runners or stems (sprigging) or plugs cut from sod (plugging). Seedbed preparation, liming, and fertilization are essentially the same regardless of the method chosen.

Seeding

Uniform seed distribution is essential. This is best obtained using a cyclone seeder (hand-held), drop spreader, conventional grain drill, cultipacker seeder, or hydraulic seeder. The grain drill and cultipacker seeders (also called grass seeder packer or Brillion drill) are pulled by a tractor and require a clean, even seedbed.

On steep slopes, hydroseeding may be the only effective seeding method. Surface roughening is particularly important when preparing slopes for hydroseeding. In contrast to other seeding methods, a rugged and even trashy seedbed gives the best results.

Hand-broadcasting should be considered only as a last resort, because uniform distribution is difficult to achieve. When hand-broadcasting of seed is necessary, minimize uneven distribution by applying half the seed in one direction and the other half at right angles to the first. Small seed should be mixed with sand for better distribution.

A “sod seeder” (no-till planter) is used to restore or repair weak cover. It can be used on moderately stony soils and uneven surfaces. It is designed to penetrate the sod, open narrow slits, and deposit seed with a minimum of surface disturbance. Fertilizer is applied in the same operation.

Inoculation of legumes

Legumes have bacteria, rhizobia, which invade the root hairs and form gall-like "nodules." The host plant supplies carbohydrates to the bacteria, which supply the plant with nitrogen compounds fixed from the atmosphere. A healthy stand of legumes, therefore, does not require nitrogen fertilizer. Rhizobium species are host specific; a given species will inoculate some legumes but not others. Successful establishment of legumes, therefore, requires the presence of specific strains of nodule-forming, nitrogen-fixing bacteria on their roots. In areas where a legume has been growing, sufficient bacteria may be present in the soil to inoculate seeded plants, but in other areas the natural Rhizobium population may be too low.

In acid subsoil material, if the specific Rhizobium is not already present, it must be supplied by mixing it with the seed at planting. Cultures for this purpose are available through seed dealers.

Sprigging and Plugging

Sprigging refers to planting stem fragments consisting of runners (stolons) or lateral, belowground stems (rhizomes), which are sold by the bushel. This method can be used with most warm-season grasses and with some ground covers, such as periwinkle. Certain dune and marsh grasses are transplanted using vertical shoots with attached roots or rhizomes. Lawn-type plants are usually sprigged much more thickly.

Broadcasting is easier but requires more planting material. Broadcast sprigs must be pressed into the top ½ to 1 inch of soil by hand or with a smooth disk set straight, special planter, cultipacker, or roller.

Plugging differs from sprigging only in the use of plugs cut from established sod, in place of sprigs. It is usually used to introduce a superior grass into an old lawn. It requires more planting stock, but usually produces a complete cover more quickly than sprigging.

Sodding

In sodding, the soil surface is completely covered by laying cut sections of turf. A commercial source of high-quality turf is required and water must be available. Plantings must be wet down immediately after planting, and kept well watered for a week or two thereafter.

Sodding, though quite expensive, is warranted where immediate establishment is required, as in stabilizing drainage ways and steep slopes, or in the establishment of high-quality turf. If properly done, it is the most dependable method and the most flexible in seasonal requirements. Sodding is feasible almost any time the soil is not frozen.

Irrigation

Irrigation, though not generally required, can extend seeding dates into the summer and insure seedling establishment. Damage can be caused by both under and over-irrigating. If the amount of water applied penetrates only the first few inches of soil, plants may develop shallow root systems that are prone to desiccation. If supplementary water is used to get seedlings up, it must be continued until plants become firmly established.

Mulching

Mulch is essential to the revegetation of most disturbed sites, especially on difficult sites such as southern exposures, channels, and excessively dry soils. The steeper the slope and the poorer the soil, the more valuable it becomes. In addition, mulch fosters seed germination and seedling growth by reducing evaporation, preventing soil crusting, and insulating the soil against rapid temperature changes.

Mulch may also protect surfaces that cannot be seeded. Mulch prevents erosion in the same manner as vegetation, by protecting the surface from raindrop impact and by reducing the velocity of overland flow. There are a number of organic and a few chemical mulches that may be useful, as well as nets and tacking materials.

Maintenance

Satisfactory stabilization and erosion control requires a complete vegetative cover. Even small breaches in vegetative cover can expand rapidly and, if left unattended, can allow serious soil loss from an otherwise stable surface. A single heavy rain is often sufficient to greatly enlarge bare spots, and the longer repairs are delayed, the more costly they become. Prompt action will keep sediment loss and repair cost down.

New seedlings should be inspected frequently and maintenance performed as needed. If rills and gullies develop, they must be filled in, re-seeded, and mulched as soon as possible. Diversions may be needed until new plants take hold.

Maintenance requirements extend beyond the seeding phase. Damage to vegetation from disease, insects, traffic, etc., can occur at any time. Herbicides and regular mowing may be needed to control weeds; dusts and sprays may be needed to control insects. Herbicides should be used with care where desirable plants may be killed. Weak or damaged spots must be relimed, fertilized, mulched, and reseeded as promptly as possible. Refertilization may be needed to maintain productive stands.

Vegetation established on disturbed soils often requires additional fertilization. Frequency and amount of fertilization can best be determined through periodic soil testing. A fertilization program is required for the maintenance of fine turf and sod that is mowed frequently. Maintenance requirements should always be considered when selecting plant species for revegetation.

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Native Grasses and Legumes for Eastern Massachusetts

Essex, Middlesex, Suffolk, Norfolk, Plymouth, Bristol, Barnstable, Dukes and Nantucket Counties

Dry Sites

Ticklegrass	Agrostis hyemalis	(no Essex) (no seed source)(cool season)
Upland Bentgrass	Agrostis prennans	(no seed source)(cool season)
Beachgrass	Ammophila brevigulata	(cool season)
Big Bluestem	Andropogon gerardii	(warm season)
Broomsedge	Andropogon virginicus	(warm season)
Common Hairgrass	Deschampsia flexuosa	(no seed source) (warm)
Deertongue grass	Dichanthehum clandestinum	(warm season)
Canada Wild Rye	Elymus canadensis	(no Cape and Islands) (cool season)
Tumble Lovegrass	Eragrostis spectabilis	(warm season)
Red Fescue	Festuca rubra	(cool season)
Nimblewill	Muhlenbergia schreberi	(no seed source)
Switchgrass	Panicum virgatum	(warm season)
Little Bluestem	Schizachyrium scoparium	(warm season)
Dropseed	Sporabolus cryptandrus	(no Cape and Islands) (warm season)
Poverty Dropseed	Sporobolus vaginiflorus	(Annual) (warm season)
Indiangrass	Sorghastrum nutans	(warm season)
Purple Sandgrass	Triplasis purpurea	(Annual) (cool season)
Wild Indigo	Baptisia tinctoria	
Showy Tick-Trefoil	Desmodium canadense	
Beach Pea	Lathyrus japonicus var. glaber	
Round Head Bush Clover	Lespideza capitata	

Moist Sites

Creeping/Marsh Bentgrass	Agrostis stolonifera var. palustris	(cool season)
Fringed Bromegrass	Bromus ciliatus	(cool season)
Deertongue Grass	Dichanthelium clandestinum	(warm season)
Canada Wild Rye	Elymus canadensis	(cool season)
Virginia Wild Rye	Elymus virginicus	(cool season)
Purple Lovegrass	Eragrostis pectinacea	(warm season)
Switchgrass	Panicum virgatum	(warm season)
Fowl Meadow Grass	Poa palustris	(cool season)
Salt Meadow Cordgrass	Spartina patens	(tidal)
Giant Cordgrass	Spartina cynocuroides	(brackish)
Eastern Gammagrass	Tripsacum dactyloides	(warm season)
Ground Nut	Apios americana	
Showy Tick-Trefoil	Desmodium canadense	

Wet Sites

Creeping Bentgrass	Agrostis stolonifera var. palustris	(cool season)
Fringed Bromegrass	Bromus ciliatus	(cool season)
Blue Joint Reed Grass	Calamagrostis canadensis	(cool season)
Stout Wood Reed	Cinna arundinacea	(cool season)
Canada Manna Grass	Glyceria canadensis	(cool season)
Fowl Meadow Grass	Glyceria striata	(cool season)
Rice Cut Grass	Leersia oryzoides	(cool season)
Marsh Mully	Muhlenbergia glomerata	(no Islands)
Smooth Cordgrass	Spartina altiniflora	(tidal)
Freshwater Cordgrass	Spartina pectinata	

Native Grasses and Legumes for Central and Western Massachusetts

Worcester, Franklin, Hampshire, Hampden and Berkshire Counties

Dry Sites

Big Bluestem	Andropogon gerardii	(warm season)
Broomsedge	Andropogon virginicus	(warm season)(no Berkshire or Franklin)
Common Hair Grass	Deschampsia flexuosa	(warm season)(no seed source)
Deertongue Grass	Dicanthelium clandestinum	(warm season)
Nodding Wild Rye	Elymus canadensis	(cool season)
Tumble Lovegrass	Erogrostis spectabolis	(warm season)
Red Fescue	Festuca rubra	(cool season)
Nimblewill	Muhlenbergia schreberi	(no seed source)
Switchgrass	Panicum virgatum	(warm season)
Little Bluestem	Schizachyrium scoparium	(warm season)
Yellow Indiangrass	Sorghastrum nutans	(warm season)
Sand Dropseed	Sporobolus cryptandrus	(no seed source)
Poverty Dropseed	Sprobolus vaginiflorus	(Annual)
Wild Indigo	Baptisia tinctoria	
Showy Tick Trefoil	Desmodium canadense	
Narrow-leafed Tick Trefoil	Desmodium paniculatum	
Round Head Bush Clover	Lespideza capitata	

Moist Sites

Creeping/Marsh Bentgrass	Agrostis stolonifera var. palustris	(cool season)
Fringed Bromegrass	Bromus Ciliatus	(cool season)
Wood Reed grass	Cinna arundinacea	(cool season)
Riverbank Wild Rye	Elymus riparius	(cool season)
Virginia Wild Rye	Elymus virginicus	(cool season)
Green Muhly	Muhlenbergia glomerata	
Switchgrass	Panicum virgatum	(warm season)
Ground Nut	Apios americana	
Showy Tick Trefoil	Desmodium canadense	

Wet Sites

Creeping/Marsh Bent Grass	Agrostis stolonifera var. palustris	(cool season)
Blue Joint Reed Grass	Calamagrostis canadensis	(cool season)
Wood Reed Grass	Cinna arundinacea	(cool season)
Canada Mannagrass	Glyceria canadensis	(cool season)
Fowl Meadow Grass	Glyceria striata	(cool season)
Rice Cut Grass	Leersia oryzoides	(cool season)
Fowl Meadow Grass	Poa palustris	(cool season)
Fresh Water Cordgrass	Spartina pectinata	

Courtesy of Natural Resources Conservation Service, Amherst, MA.
Source: Massachusetts Natural Heritage and Endangered Species Program

Tree and Shrub Plantings

Trees For Dry Soils

Scientific Name	Common Name	Mature Height
Acer Negundo	Box Elder	60’
Betula populifolia	Gray Birch	30’
*Pinus resinosa**	Red Pine	80’
*Pinus strobus**	Eastern White Pine	90’
*Pinus sylvestris**	Scotch Pine	60’
Populus tremuloides	Quaking Aspen	50’

Shrubs For Dry Soils

Scientific Name	Common Name	Mature Height
Acer ginnala	Amur Maple	20’
Ceanothus americanus	New Jersey Tea	2’
Comptonia peregrina	Sweet Fern	3’
Corylus americana	American Hazelnut	6’
Gaylussacia baccata	Black Huckleberry	3’
*Juniperus communis**	Common Juniper	3-30’
*Juniperus virginiana**	Red-cedar	10-90’
Myrica pennsylvanica	Bayberry	5’
Rhus aromatica	Fragrant Sumac	3’
Rhus copallina	Shining Sumac	30’
Rhus glabra	Smooth Sumac	9-15’
Rhus typhina	Stagborn Sumac	30’
Rosa rugosa	Rugosa Rose	6’
Rosa virginiana	Virginia Rose	3’
Viburnum lentago	Nannyberry	15’

Trees For Moderately Moist Soils

Scientific Name	Common Name	Mature Height
Fraxinus pennsylvanica	Green Ash	50’
Picea abies*	Norway Spruce	150’
Picea pungens*	Colorado Spruce	100’
Pinus strobus*	Eastern White Pine	100-150’
Populus nigra ‘Italica’	Lombardy Poplar	90’
Pseudotsuga menziesii*	Douglas-fir	100-300’
Salix nigra	Black Willow	40’
Sorbus americana	American Mountain Ash	25’
Thuja occidentalis*	American Arbor-vitae	60’
Tilia americana	Basswood	60-80’
Tsuga canadensis*	Canada Hemlock	90’

**evergreen*

Shrubs For Moderately Moist Soils

Scientific Name	Common Name	Mature Height
Cornus amomum	Silky Dogwood	6-10’
Cornus racemosa	Gray-stemmed Dogwood	6’
Corylus americana	American Hazelnut	6’
Corylus cornuta	Beaked Hazelnut	12’
Forsythia Z intermedia	Border Forsythia	9’
Hamemelis virginiana	Common Witchhazel	15’
Ilex glabra	Inkberry	5’
Myrica pennsylvanica	Bayberry	5’
Rhododendron maximum	Rhododendron	20’

**evergreen*

Trees For Very Moist Soils

Scientific Name	Common Name	Mature Height
Acer negunda	Box Elder	60’
Acer rubrum	Red Maple	60’
Acer saccharinum	Silver Maple	70’
Fraxinus pennsylvanica	Green Ash	40’
Fraxinus nigra	Black Ash	45’
Larix laricina	American Larch	60’
Platanus occidentalis	Sycamore	100’
Populus deltoides	Eastern Cottonwood	70’
Salix nigra	Black Willow	40’
Salix bebbiana	Bebb Willow	25’
Thuja occidentalis	White Cedar	60’

Shrubs For Very Moist Soils

Scientific Name	Common Name	Mature Height
Alnus rugosa	Speckled Alder	20’
Alnus serulata	Smooth Alder	20’
Aronia arbutifolia	Red Chokeberry	20’
Clethra alnifolia	Sweetpepper Bush	10’
Cornus amomum	Silky Dogwood	8’
Cornus stolonifera	Red Osier Dogwood	8’
Ilex verticillata	Winterberry	10’
Lonicera canadensis	Canada Honeysuckle	15’
Lyonia ligustrium	Maleberry	8’
Rhododendrum canadensis	Rhodora***	12’
Rubus odoratus	Purple Flowering Raspberry	8’
Salix discolor	Pussy Willow	10’
Salix lucida	Shining Willow	8’
Sambucus canadensis	Elderberry	10’
Vaccinium corymbosum	Highbush Blueberry	10’
Viburnum cassinoides	Wild Raisin	12’
Viburnum acerifolium	Mapleleaf Viburnum	6’
Viburnum dentatium/recognitum	Arrowwood	8’
Viburnum trilobum	Highbush Cranberry	15’

Spacing Distance

For water erosion control:

Small to medium shrubs	1’ x 1’ to 2’ x 2’
Medium to large shrubs	2’ x 2’ to 4’ x 4’
Trees	4’ x 4’ to 8’ x 8’

For wind erosion control:

Small to medium shrubs	2’ x 2’ to 4’ x 4’
Medium to large shrubs	4’ x 4’ to 6’ x 6’
Trees	6’ x 6’ to 10’ x 10’

References

Technical assistance provided by Natural Resources Conservation Service staff at Amherst, MA, Massachusetts Native Plant Advisory Committee, and the Massachusetts Natural Heritage and Endangered Species Program.

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Soil Bioengineering

Soil bioengineering methods use vegetative materials in combination with more traditional landshaping, rock placement, and structural techniques. Bioengineering techniques can be used for immediate protection of slopes against surface erosion, cut and fill slope stabilization, earth embankment protection, and small gully repairs.

Stems and branches of living plants are used as soil reinforcing and stabilizing material. Techniques include live staking, fascines, brushlayers, branchpacking, and live gully repair. Roots develop and foliage sprouts when the vegetative cuttings are placed in the ground. The resulting vegetation becomes a major structural component of the bioengineering system.

Bioengineering combines biological elements with engineering design principles. The requirements for both must be considered when planning and designing measures. Engineering requirements may call for highly compacted soil for fill slopes, for example, while plants prefer relatively loose soil. Using a sheepsfoot roller for compaction is a solution that would integrate biological and engineering requirements because it compacts the soil, but also allows plant establishment in resulting depressions in the slope.

Vegetation can be used with rigid construction such as surface armoring, gravity retaining walls, and rock buttresses to create vegetated structures. Vegetation enhances the structures and helps reduce surface erosion, but usually does not provide any reinforcement benefits.

Vegetated cribwalls, gabions, and rock walls are bioengineering techniques that use porous structures with openings through which vegetative cuttings are inserted and established. The structural elements provide immediate resistance to sliding, erosion, and washout. As vegetation becomes established, roots develop, binding the slope together in a unified, coherent mass. Over time, the structural elements diminish in importance as the vegetation increases in strength and functionality.

Contact the local Conservation Commission regarding any stream crossing or other work conducted in a wetland resource area. The Massachusetts Wetland Protection Act requires that the proponent file a "Request for Determination of Applicability" or "Notice of Intent."

Material in this section is adapted from Chapter 18, *Soil Bioengineering for Upland Slope Protection and Erosion Reduction*, of the Natural Resources Conservation Service *Engineering Field Handbook,* and from *Stormwater Management Manual for the Puget Sound Basin*, Washington State Department of Ecology.

Vegetative Components

Vegetation offers long-term protection against surface erosion on slopes. It provides some protection against shallow mass movement. Vegetation helps to prevent surface erosion by:

- Binding and restraining soil particles in place,
- Reducing sediment transport,
- Intercepting raindrops,
- Retarding velocity of runoff,
- Enhancing and maintaining infiltration capacity,
- Minimizing freeze-thaw cycles of soils susceptible to frost.

Woody vegetation has deeper roots and provides greater protection against shallow mass movement by:

- Mechanically reinforcing the soil with roots,
- Depleting soil-water through transpiration and interception,
- Buttressing and soil arching action from embedded stems.

Examples

Fascines:

Woody species, such as shrub willow or shrub dogwood, are used for “live fascines” -long bundles of branch cuttings bound together into sausage-like bundles. The bundles are placed with the stems oriented generally parallel to the slope contour.

Live fascines dissipate the energy of flowing water by trapping debris and providing a series of benches on which grasses, seedlings, and transplants establish more easily. Portions of the live fascines root and become part of the stabilizing cover. Live fascines provide an immediate increase in surface stability and can further improve soil stability to depths of two to three feet as roots develop.

Brushlayering:

Live branches or shoots of such woody species as shrub willow, dogwood, or privet are placed in successive layers with the stems generally oriented perpendicular to the slope contour. This orientation is the optimal direction for maximum reinforcing effect in a slope. Brushlayering can improve soil stability to depths of 4 to 5 feet.

Structural Components

Structural measures help stabilize a slope against shallow mass movement and protect the slope against rill and gully formation. Structures also help establish vegetation on steep slopes or in areas subject to severe erosion. They may make it feasible to establish plants on slopes steeper than would normally be possible. Structures stabilize slopes during critical seed germination and root growth. Without this stabilization, vegetative plantings would fail during their most vulnerable time.

Materials

Structures can be built from natural or manufactured materials. Natural materials, such as earth, rock, stone, and timber, usually cost less, are environmentally more compatible, and are better suited to vegetative treatment or slight modifications than are manufactured materials. Natural materials may also be available onsite at no cost.

Some structures are comprised of both natural and manufactured materials. Examples include concrete cribwalls, steel bin walls, gabion walls or revetments, welded wire or polymeric geogrid walls, and reinforced earth. In these cases steel and concrete mostly provide rigidity, strength, and reinforcement, whereas stone, rock, and soil provide mass. These types of structures have spaces that are often planted with herbaceous or woody vegetation.

Retaining Structures

A retaining structure of some type is usually required to protect and stabilize extremely steep slopes. Low retaining structures at the toe of a slope make it possible to grade the slope back to a more stable angle that can be successfully revegetated without loss of land at the crest. Structures are generally capable of resisting much higher lateral earth pressures and shear stresses than vegetation.

Grade Stabilization Structures

Grade stabilization structures are used to control and prevent gully erosion. A grade stabilization structure reduces the grade above it and dissipates the excess energy of flowing water within the structure itself. Debris and sediment tend to be deposited and trapped upstream of the structure. This, in turn, permits establishment of vegetation behind the structure, which further stabilizes the ground. Grade stabilization structures may range from a series of simple timber check darns to complex concrete overfall structures and earth embankments with pipe spillways.

Gully control is an example of the integration of structures and vegetation. Structural measures may be required in the short term to stabilize critical locations. The long-term goal is to establish and maintain a vegetative cover that prevents further erosion. Vegetation alone will rarely stabilize gully headcuts because of the concentrated water flow, overfalls, and pervasive forces that promote gully enlargement in an unstable channel system. Initially, the vegetation and the structure work together in an integrated fashion. The ultimate function of these structures, however, is to help establish vegetation which will provide longterm protection.

Factors to Consider

Bioengineering integrates the characteristics of vegetative components with those of structural components. The resulting systems and their components have benefits and limitations that need to be considered prior to selecting them for use.

Bioengineering is not appropriate for all sites and situations. In some cases, conventional vegetative treatment (e.g., grass seeding and hydro mulching) works satisfactorily at less cost. in other cases, the more appropriate and most effective solution is a structural retaining system alone or in combination with bioengineering.

Environmental Compatibility

Bioengineering systems generally require minimal access for equipment and workers and cause relatively minor site disturbance during installation. These are generally important considerations in environmentally sensitive areas, such as parks, woodlands, and scenic corridors where aesthetic quality, wildlife habitat, and similar values may be critical.

Cost Effectiveness

Combined slope protection systems are more cost effective than the use of either vegetative treatments or structural solutions alone in some instances. Where construction methods are labor intensive and labor costs are reasonable, the combined systems may be especially cost effective. If labor is scarce or costly, however, bioengineering systems may be less practical than structural measures.

Using native plant materials accounts for some of the cost effectiveness because plant costs are limited to labor for harvesting and handling and direct costs for transporting the plants to the site.

Planting Times

Bioengineering systems are most effective when they are installed during the dormant season, usually the late fall winter, and early spring. This often coincides with the time that other construction work is slow.

Constraints on planting times or the availability of the required quantities of suitable plant materials during allowable planting times may limit the usefulness of bioengineering methods.

Difficult Sites

Bioengineering may be an alternative for small, sensitive, or steep sites where the use of machinery is not feasible and hand labor is a necessity. Rapid vegetative establishment may be difficult, however, on extremely steep slopes.

Suitable soils are needed for plant growth. Rocky or gravelly slopes may lack sufficient fines or moisture to support plant growth. Restrictive layers in the soil, such as hardpans, may restrict root growth.

Vegetation would be of limited use on slopes that are exposed to high velocity water flow or constant inundation.

Harvesting Local Plant Material

Vegetation can often be obtained as dormant cuttings from local stands of willows and other suitable species. This stock is already well suited to the climate, soil conditions, and available moisture and is a good candidate for survival. Using local plant materials and gathering in the wild could result in short supplies or unacceptable depletion of site vegetation.

Some localities have prohibitions against gathering native plants and materials must be purchased from commercial sources.

Biotechnical Strengths

Bioengineering systems are strong initially and grow stronger with time as vegetation becomes established. In some instances, the primary role of the structural component is to give the vegetation a better chance to become established. Bioengineering systems can usually withstand heavy rainfalls immediately after installation. Even if established vegetation dies, the plant roots and surface residue still furnish protection during reestablishment.

Design Considerations

Consider site topography, geology, soils, vegetation, and hydrology. Avoid extensive grading and earthwork in critical areas. Perform soil tests to determine if vigorous plant growth can be supported.

Topography and Exposure

Note the degree of slope in stable and unstable areas. Also note the presence or lack of moisture. The potential for success of bioengineering treatments can best be determined by observing existing stable slopes in the vicinity of the project site.

Note the type and density of existing vegetation in areas with and without moisture and on slopes facing different directions. Certain plants grow well on east-facing slopes, but will not survive on south-facing slopes.

Look for areas of vegetation that may be growing more vigorously than other site vegetation. This is generally a good indicator of excess moisture, such as seeps and a perched water table, or it may reflect a change in soils.

Geology and Soils

Note evidence of past sliding. If site evidence exists, determine whether the slide occurred along a deep or shallow failure surface. Leaning or deformed trees may indicate previous slope movement or downhill creep. In addition to site evidence, check aerial photos, which can reveal features that may not be apparent from a site visit.

Determine soil type and depth. Use the soil survey report, if available.

Hydrology

Determine the drainage area. Note whether water can be diverted away from the problem area.

Are there concentrated discharges?

Calculate peak flows through the project area.

If a seep area is noted, locate the source of the water. Determine whether the water can be intercepted and diverted away from the slope face.

Vegetation

Retain existing vegetation, limit the removal of vegetation. Vegetation provides excellent protection against surface erosion and shallow slope failures.

Bioengineering measures are designed to aid or enhance the reestablishment of vegetation.

Limit cleared area to the smallest practical size.

Limit duration of disturbance to the shortest practical time.

Remove and store existing woody vegetation that may be used later in the project.

Schedule land clearing during periods of low precipitation whenever possible.

Earthwork

Sites usually require some earthwork prior to the installation of bioengineering systems. A steep undercut or slumping bank, for example, requires grading to flatten the slope for stability. The degree of flattening depends on the soil type, hydrologic conditions, geology, and other site factors.

Scheduling and Timing

Planning and coordination are needed to achieve optimal timing and scheduling. The seasonal availability of plants or the best time of year to install them may not coincide with the construction season or with tight construction schedules. In some cases, rooted stock may be used as an alternative to unrooted dormant season cuttings.

Vegetative Damage to Inert Structures

Vegetative damage to inert structures may occur when inappropriate species or plant materials that exceed the size of openings in the face of structures are used. Vegetative damage does not generally occur from roots. Plant roots tend to avoid porous, open-faced retaining structures because of excessive sunlight, moisture deficiencies, and the lack of a growing medium.

Moisture Requirements and Effects

The backfill behind a stable retaining structure needs specific mechanical and hydraulic properties. Ideally, the fill is coarse-grained, free-draining, granular material. Excessive amounts of clay, silt, and organic matter are not desirable. Free drainage is essential to the mechanical integrity of an earth retaining structure and also important to vegetation, which cannot tolerate waterlogged soil conditions.

Establishing and maintaining vegetation, however, usually requires some fine-grained soils and organic matter in the soil to provide adequate moisture and nutrient retention. These requirements can often be satisfied without compromising the engineering performance of the structure. With cribwalls, for example, adequate amounts of fine-grained soils or other amendments can be incorporated into the backfill. Gabions can have the spaces between rocks filled with and soil to facilitate growth of vegetation. Woody vegetative cuttings can be placed between the baskets during filling and into the soil or backfill beyond the baskets. The needs of plants and the requirements of structures must be taken into account when designing a system.

Construction Materials and Techniques

General Considerations

Bioengineering measures have certain requirements and capabilities. Plant species must be suitable for the intended use and adapted to the site's climate and soil conditions. Species that root easily, such as willow, are required for such measures as live fascines, brushlayer, and live staking or where unrooted stems are used with structural measures. See the end of this section for a list of plant species suitable for use in bioengineering applications in Massachusetts.

Rooted plants and live dormant cuttings are living materials and must be handled properly to avoid excess stress, such as drying or exposure to heat. They must be installed in moist soil and adequately covered. The soil must be compacted to eliminate or minimize air pockets around the buried stems. If soils are not at or near moisture capacity, the installation should be delayed unless deep and regular irrigation can be provided during and following installation.

Bioengineering systems are best installed in the late fall at the onset of plant dormancy; either in the winter, as long as the ground is not frozen, or in early spring before growth begins. Installation after initial spring growth may be successful in some cases, but the risks of failure are high. Summer installation is not recommended. Rooted plants can be used, but they are sometimes less effective and more expensive.

All installations should be inspected regularly and provisions made for prompt repair if needed. Initial failure of a small portion of a system normally can be repaired easily and inexpensively. Neglect of small failures, however, can often result in the failure of large portions of a system.

Properly designed and installed vegetative portions of systems will become self-repairing to a large extent. Periodic pruning and replanting may be required to maintain healthy and vigorous vegetation. Structural elements, such as cribwalls, rock walls, and gabions, may require maintenance and/or replacement throughout their life. Where the main function of structural elements is to allow vegetation to become established and take over the role of slope stabilization, the eventual deterioration of the structures is not a cause for concern.

Bioengineering Materials

Plant tolerances to deposition, flooding, drought, and salt should be considered in selecting species for adverse site conditions.

Locating and Selecting Plant Materials

Commercial Sources

Commercially grown plant materials are suitable sources of vegetation for use in bioengineering systems; however, it is necessary to allow adequate lead time for their procurement and delivery.

Native Species

Correctly selected live dormant cuttings harvested from existing stands of living woody vegetation are the preferred bioengineering materials. The use of indigenous live materials requires careful selection, harvesting, handling, and transporting. They should result in plants that have deep and strong root systems, are relatively inexpensive, are usually effective, and can be installed quickly.

Live plant materials can be cut from existing native or naturalized stands found near the project site or within practical hauling distance. The source site must contain plant species that will propagate easily from cuttings. Cuttings are normally ½ to 2 inches in diameter and range in length from 2 to 6 feet.

Chain saws, bush axes, loppers, and prunners are recommended for cutting living plant material. Safety precautions must be followed when using these tools. Onsite plant material should be harvested with great care. In some places a large area can be cut, but other sites require selective cutting. Cuts should be made at a blunt angle, 8 to 10 inches from the ground, to assure that the source sites will regenerate rapidly and in a healthy manner.

The harvesting site should be left clean and tidy. Remnant materials that are too large for use in bioengineering projects should be chipped or left in piles for wildlife cover. A site may be needed again for future harvesting and should be left in a condition that will enhance its potential for regeneration.

Binding and Storage

Live cuttings should be bundled together securely at the collection site for easy loading and handling and for protection during transport. Side branches and brushy limbs should be kept intact.

Transporting

The bundles of live cuttings should be placed on the transport vehicles in an orderly fashion to prevent damage and facilitate handling. They should be covered with a tarpaulin during transportation to prevent drying and additional stress.

Handling

Live cuttings should arrive on the job site within eight hours of harvest and should be installed immediately. This is especially critical when the ambient temperature is 50 degrees F or above.

Live cuttings not installed on the day they arrive should be placed in controlled storage conditions and protected until they can be installed. When in storage, the cuttings must receive continuous shade, must be sheltered from the wind, and must be continuously protected from drying by being heeled into moist soils or stored in uncontaminated water. All live cuttings should be removed from storage and used within 2 days of harvest.

Installing Plant Materials

Timing

Installation of live cuttings should begin concurrently with earth moving operations if they are carried out during the dormant season. All construction operations should be phased together whenever possible. The best time for installation of bioengineering systems is during the dormant season.

Planting Medium

Bioengineering projects ideally use onsite stockpiled topsoil as the planting medium of choice. Gravel is not suitable for use as fill around live plant materials. A planting medium is needed that includes fine-grained soil and organic material, and is capable of supporting plant growth.

Muddy soils that are otherwise suitable should not be used until they have been dried to a workable moisture content. Heavy clays should be mixed with organic soils to increase porosity. Select soil backfill does not need to be organic topsoil but it must be able to support plant growth.

Soil samples should be taken of the onsite materials prior to planting live woody cuttings. Soil samples should also be taken of all fill materials that are brought to the site prior to use. Nutrient testing should include analyses for plant nutrients, metal contents, and pH. Laboratory reports should include recommended fertilizer and lime amendments for woody plant materials.

All fill soil around the vegetative cuttings should be compacted to densities approximating the surrounding natural soil densities. The soil around plants should be free of voids.

Establishment Period

Bioengineering measures should be checked periodically after installation. Recommended schedule:

First two months:
Inspect biweekly. Check for insect infestations, soil moisture, and other conditions that could lead to poor survivability. Take action, such as the application of supplemental water, to correct any problems.

Next six months:
Inspect monthly. Systems not in acceptable growing condition should be noted and, as soon as seasonal conditions permit, should be removed from the site and replaced with materials of the same species and sizes as originally specified.

Initial 2-year establishment period:
Perform reestablishment work as needed every six months. This will usually consist of replacing dead material.
Make additional inspections during periods of drought or heavy rains. Damaged sections should always be repaired immediately.

Live Staking

Live staking involves the insertion and tamping of live, rootable vegetative cuttings into the ground. If correctly prepared and placed, the live stake will root and grow. Stakes create a living root mat that stabilizes the soil by reinforcing and binding soil particles together and by extracting excess soil moisture.

Live staking increases the opportunity for natural invasion and establishment of other plants from the surrounding plant community.

Recommended Uses

Most willow species root rapidly and begin to dry out a slope soon after installation. Live staking is appropriate for repair of small earth slips and slumps that frequently are wet.

May be used for pegging down surface erosion control materials.

Can be used to stabilize intervening area between other bioengineering techniques, such as live fascines.

Well-adapted to relatively uncomplicated site conditions when construction time is limited and an inexpensive method is necessary.

Construction Recommendations

Select cuttings ½ to 1 ½ inches in diameter and 2 to 3 feet long.

The cuttings must have side branches cleanly removed and the bark intact.

The ends should be cut at an angle for easy insertion into the soil. The top should be cut square.

Cuttings should be installed the same day that they are prepared.

Installation

Tamp the live stake into the ground at right angles to the slope. The installation may be started at any point on the slope face.

The live stakes should be installed 2 to 3 feet apart using triangular spacing. The density of the installation will range from 2 to 4 stakes per square yard.

The buds should be oriented up.

About four-fifths of the length of the live stake should be installed into the ground. Pack soil firmly around stakes after installation.

Be careful not to split the stakes during installation. Stakes that do split should be replaced.

An iron bar can be used to make a pilot hole in firm soil. Drive the stake into the ground with a dead blow hammer (hammer head filled with shot or sand).

Dormant Woody Plantings

This involves the use of live, dormant-stem cuttings of woody plant species from ½ to 3 inches or more in diameter. The plantings create a living root mat that stabilizes the soil by reinforcing and binding soil particles together and by extracting excess soil moisture.

Recommended Uses

Dormant plantings are appropriate for repair of small earth slips and slumps that frequently are wet.

Can be used to stabilize intervening area between other bioengineering techniques, such as live fascines.

A technique for relatively uncomplicated site conditions when construction time is limited and an inexpensive method is necessary.

Materials and Preparation

Cuttings, stakes and posts to be used as live dormant woody materials should be obtained from moisture-loving species that will either root naturally or respond to treatment with rooting hormones. Always select healthy materials native or adaptable to the planting site.

The proper preparation and handling of selected materials is very important. Make clean cuts and avoid split ends.

Always plant materials with the butt end down. The butt end should be tapered to mark it for proper orientation as well as facilitate driving it into the soil if done so manually. The top end should be flat, especially on stakes and posts, to facilitate manual driving.

Trim lateral branches to leave the bark ridge and branch collar intact.

The diameter and length of the plant materials varies with the type:

Dormant "cutting" - The diameter of cuttings should be a minimum of one-half inch and a maximum of less than one (1) inch. Cuttings should be at least 12 inches but less than 18 inches in length.

Dormant "stake" - Stakes should be one to three inches in diameter at the top and 18 inches to six feet in length.

Dormant "post" - Posts should be greater than three inches in diameter at the top end. Length will vary with the depth to saturated soil and the difference in feet between the channel bottom and low bank elevation. However, posts should be a minimum length equal to the difference in feet between the lowest point of channel scour and the low bank elevations or 7 feet, whichever is less.

All "stakes" and "posts" should extend a minimum of two feet below the maximum depth of the streambed scour.

There should be at least two lateral buds and/or terminal bud scars above the ground on "cuttings." A terminal bud scar should be within 1 to 4 inches of the top. Cuttings put out the largest number and strongest shoots just below a terminal bud scar (annual growth scar).

Planting materials must not be allowed to dry out. They should be kept moist and covered during transport to the planting site and during planting operations. Material should be kept submerged in water up to the time of planting. It is best to plant materials the same day they are cut and prepared. One exception is Eastern Cottonwood, which has exhibited increased survival rates if soaked in water for 1 to 2 days prior to planting.

Select native or naturalized species that root readily with or without the use of rooting hormones. Rooting hormones, if used, should be applied according to manufacturers' recommendations.

Wood species with short, dense, flexible top growth and large, deep, fibrous root systems are recommended. Other desirable characteristics include rapid initial growth, ability to reproduce by seed or vegetatively, and resistance to insects and diseases.

Layout

Dormant "stakes" and "posts" should be placed in staggered rows at two-foot by two-foot, two-foot by four-foot, or four-foot by four-foot spacings. Dormant "cuttings" may be scattered between rows of "stakes" and "posts."

On eroding streambanks over 15 feet high, use a minimum of 4 rows of dormant "stakes" or "posts."

Installation

All materials should be cut and installed while in a dormant stage. The following periods are recommended for practice installation: November 1 until ground becomes frozen, or February 1 to April 1 provided ground is not frozen or buds have not broken dormancy.

Be sure that the planting material is right side up (butt end in the ground).

Set the materials as deep as possible with at least the bottom 12 inches into a saturated soil layer. Deep planting insures an adequate moisture supply for root development, minimizes water loss due to transpiration and prevents root breakage caused by movement between the planting material and the soil during high velocity water flows.

Avoid excessive damage to the bark of the planting material, especially stripping.

Be sure there is good contact between the soil and planting material. "Dormant cuttings" will have the soil tamped around them. Dormant materials may be installed using an iron bar for "cuttings" and a post hole digger, powered auger or a metal ram on a backhoe or similar equipment for "stakes" and "posts."

In soft, nonrestricted soils, "stakes" or "posts" may be manually driven into place using a wooden maul. If a sledge is used, care must taken to avoid splitting the planting material. Extreme care is needed in driving the stakes or posts, and should be limited to soils such as sandy soils, where use of the other methods is not feasible.

Post lengths should be extended 4 to 6 inches to allow for a new flat cut to eliminate any damaged materials after manual driving. At least 40 percent, and preferably 50 percent or more, of the planting material should be below ground level after planting.

Where damage by beaver may occur, treating materials with a repellant, such as ropel, or enclosing them with chicken wire is recommended.

All "stakes" and "posts" located in the stream channel should have a minimum of 12 inches extending above the normal water level.

Recommended Species

Species selection should consider the position of the plant in the bank profile.

Zone 1

Below normal waterline to upper limit of saturation area kept moist by capillary water movement. This zone includes the greatest potential for periodic inundations and the least moisture stress.

Zone 2

Area from upper limit of Zone 1 to 2-3 feet from the top of the bank. This area may be subject to rapid drying and greater moisture stress.

Zone 3

Area 2-3 feet below the top of the bank to a minimum of 30 feet into the floodplain.

Plant Zone	Common Name/Scientific Name	Growth Form
1	Black Willow* Salix nigra	Tree
1	Bankers Willow* Salix cottettii	Shrub
1	Purple-osier willow* Salix purpurea	Shrub
1	Sandbar Willow* Safix interior	Tree
1	Carolina Willow* Safix caroliniana	Tree
1	Peach-leaved Willow* Salix amycdaloides	Tree
1	Buttonbush* Cephalanthis occidetalis	Shrub
1,2,3	Red-osier Dogwood* Comus stolonifera	Shrub
2,3	Silky Dogwood Comus amomum	Shrub
2,3	Flowering Dogwood Comus florida	Tree
2,3	Green Ash Fraxinus pennsylvanica	Tree
2,3	Sycamore* Platanus occidentalis	Tree
1,2,3	Bald Cypress Taxodium distichum	Tree
1,2	River Birch Betula nigra	Tree
1,2,3	Eastern Cottonwood* Populus deltoides	Tree
1,2,3	Swamp Cottonwood* Populus heterophylla	Tree

**These species are suitable for use as dormant woody cuttings, stakes or posts. All species of willow and cottonwood do not require hormone treatment for rooting.*

Fascines

Fascines are long bundles of live branch cuttings bound together into sausage-like structures. When cut from appropriate species and properly installed with live and dead stout stakes, fascines will root and immediately begin to stabilize slopes.

Advantages

An effective stabilization technique for slopes.

Immediately reduces surface erosion or rilling.

Enhances vegetative establishment by creating a microclimate conducive to plant growth.

Capable of trapping and holding soil on the face of the slope, thus reducing a long slope, into a series of shorter slopes.

Recommended Uses

To protect slopes from shallow slides (1 to 2 foot depth).

On steep, rocky slopes, where digging is difficult.

Construction guidelines

Fascines should be placed in shallow contour trenches on dry slopes and at an angle on wet slopes to reduce erosion and shallow face sliding. This causes little site disturbance when installed by a trained crew.

Live materials

Cuttings must be from species, such as young willows or shrub dogwoods, that root easily and have long, straight branches.

Live material sizes and preparation
Cuttings tied together to form live fascine bundles may vary in length from 5 to 30 feet or longer, depending on site conditions and limitations in handling.

The completed bundles should be 6 to 8 inches in diameter, with all of the growing tips oriented in the same direction. Stagger the cuttings in the bundles so that tops are evenly distributed throughout the length of the uniform-sized bundle. Live stakes should be 2 ½ feet long in cut slopes and 3 feet long in fill slopes.

Inert materials
String used for bundling should be untreated twine.

Dead stout stakes used to secure the fascines should be 2 ½-foot long, untreated, 2 by 4 lumber. Each length can be cut again diagonally across the 4-inch face to make two stakes from each length. Use new, sound, unused lumber. Any stakes that shatter during installation should be discarded.

Installation

Prepare the fascine bundles and live stakes immediately before installation.

Beginning at the base of the slope, dig a trench on the contour just large enough to contain the live fascine. The trench will vary in width from 12 to 18 inches, depending on the angle of the slope to be treated. The depth will be 6 to 8 inches, depending on the individual bundle's final size. Place the live fascine into the trench.

Drive the dead stout stakes directly through the live fascine every 2 to 3 feet along its length. Extra stakes should be used at connections or bundle overlaps. Leave the top of the stakes flush with the installed bundle.

Live stakes are generally installed on the downslope side of the bundle. Drive the live stakes below and against the bundle between the previously installed dead stout stakes. The live stakes should protrude 2 to 3 inches above the top of the live fascine. Place moist soil along the sides of the live fascine. The top of the fascine should be slightly visible when the installation is completed.

Repeat the preceding steps to the top of the slope; at intervals on the contour or at an angle up the face of the bank. When possible, place one or two rows over the top of the slope.

Long straw or similar mulching material should be placed between rows on 2.5:1 or flatter slopes, while slopes steeper than 2.5:1 should have jute mesh or similar material placed in addition to the mulch.

Brushlayer

Brushlayering consists of placing live branch cuttings in small benches excavated into the slope. The benches can range from 2 to 3 feet wide. These systems are recommended on slopes up to 2:1 in steepness and not to exceed 15 feet in vertical height.

Brushlayers are similar to fascine systems because both involve the cutting and placement of live branch cuttings on slopes. The two techniques differ principally in the orientation of the branches and the depth to which they are placed in the slope. In brushlayering, the cuttings are oriented more or less perpendicular to the slope contour. The perpendicular orientation is more effective for earth reinforcement and mass stability of the slope.

Brushlayer branches serve as reinforcing units. The portions of the brush that protrude from the slope face assist in retarding runoff and reducing surface erosion.

Purpose

Brushlayers perform several immediate functions in erosion control earth reinforcement, and mass stability of slopes:

- Breaking up the slope length into a series of shorter slopes separated by rows of brushlayer.
- Reinforcing the soil with the unrooted branch stems.
- Reinforcing the soil as roots develop, adding significant resistance to sliding or shear displacement.
- Providing slope stability and allowing vegetative cover to become established.
- Trapping debris on the slope.
- Aiding infiltration on dry sites.
- Drying excessively wet sites.
- Adjusting the site's microclimate, thus aiding seed germination and natural regeneration.
- Improving slope stability by acting as horizontal seepage drains.

Construction Recommendations

Live material sizes

Branch cuttings should be ½ to 2 inches in diameter and long enough to reach the back of the bench. Side branches should remain intact for installation.

Installation

Starting at the toe of the slope, benches should be excavated horizontally, on the contour, or angled slightly down the slope, if needed to aid drainage. The bench should be constructed 2 to 3 feet wide.

The surface of the bench should be sloped so that the outside edge is higher than the inside.

Live branch cuttings should be placed on the bench in a crisscross or overlapping configuration.

Branch growing tips should be aligned toward the outside of the bench.

Backfill is placed on top of the branches and compacted to eliminate air spaces. The brush tips should extend slightly beyond the fill to filter sediment.

Each lower bench is backfilled with the soil obtained from excavating the bench above.

Long straw or similar mulching material with seeding should be placed between rows on 3:1 or flatter slopes, while slopes steeper than 3:1 should have jute mesh or similar material placed in addition to the mulch.

The brushlayer rows should vary from 3 to 5 feet apart, depending upon the slope angle and stability.

Branchpacking

Branchpacking consists of alternating layers of live branch cuttings and compacted backfill to repair small localized slumps and holes in slopes. Branchpacking provides immediate soil reinforcement.

Where Practice Applies

- Effective in earth reinforcement and mass stability of small earthen fill sites.
- Produces a filter barrier, reducing erosion and scouring conditions.
- Repairs holes in earthen embankments other than dams where water retention is a function.

Construction Recommendations

Live material

Live branch cuttings may range from ½ inch to 2 inches in diameter. They should be long enough to touch the undisturbed soil at the back of the trench and extend slightly from the rebuilt slope face.

Inert material

Wooden stakes should be 5 to 8 feet long and made from 3- to 4-inch diameter poles or 2 by 4 lumber, depending upon the depth of the particular slump or hole.

Installation

Starting at the lowest point, drive the wooden stakes vertically 3 to 4 feet into the ground. Set them 1 to 1 ½ feet apart.

A layer of living branches 4 to 6 inches thick is placed in the bottom of the hole, between the vertical stakes, and perpendicular to the slope face. They should be placed in a crisscross configuration with the growing tips generally oriented toward the slope face. Some of the basal ends of the branches should touch the back of the hole or slope.

Subsequent layers of branches are installed with the basal ends lower than the growing tips of the branches.

Each layer of branches must be followed by a layer of compacted soil to ensure soil contact with the branch cuttings.

The final installation should match the existing slope. Branches should protrude only slightly from the filled face.

The soil should be moist or moistened to insure that live branches do not dry out.

The live branch cuttings serve as “tensile inclusions” for reinforcement once installed. As plant tops begin to grow, the branchpacking system becomes increasingly effective in retarding runoff and reducing surface erosion. Trapped sediment refills the localized slumps or holes, while roots spread throughout the backfill and surrounding earth to form a unified mass. Branchpacking is not effective in slump areas greater than 4 feet deep or 5 feet wide.

Live gully repair

A live gully repair utilizes alternating layers of live branch cuttings and compacted soil to repair small rills and gullies. Similar to branchpacking.

Limited to rills or gullies which are a maximum of 2 feet wide, 1 foot deep, and 15 feet long.

Advantages

The installed branches offer immediate reinforcement to the compacted soil and reduce the velocity of concentrated flow of water.

Provides a filter barrier that reduces rill and gully erosion.

Construction Recommendations

Live material sizes

Live branch cuttings may range from ½ inch to 2 inches in diameter. They should be long enough to touch the undisturbed soil at the back of the rill or gully and extend slightly from the rebuilt slope face.

Inert materials

Fill soil is compacted in alternate layers with live branch cuttings.

Installation

Starting at the lowest point of the slope, place a 3- to 4-inch layer of branches at lowest end of the rill or gully and perpendicular to the slope.

Cover with a 6 to 8 inch layer of fill soil.

Install the live branches in a crisscross fashion. Orient the growing tips toward the slope face with basal ends lower than the growing tips.

Follow each layer of branches with a layer of compacted soil to ensure soil contact with the live branch cuttings.

Vegetated Structures

Vegetated structures consist of either low walls or revetments (concrete or rock and mortar) at the foot of a slope with plantings on the interposed benches.

A structure at the foot of a slope protects the slope against undermining or scouring and provides a slight buttressing effect. In the case of low walls, it allows regrading of the slope face to a more stable angle without excessive retreat at the crest.

Vegetation planted on the crest of the wall and the face of the slope protects against, erosion and shallow sloughing. In the case of tiered structures, the roots of woody plants grow into the soil and backfill within the structure, binding them together. The foliage in front covers the structure and enhances its appearance.

Low Wall/Slope Face Plantings

A low retaining structure at the foot of a slope makes it possible to flatten the slope and establish vegetation. Vegetation on the face of the slope protects against both surface erosion and shallow face sliding.

Several types of retaining structures can be used as low walls. The simplest type is a “gravity wall” that resists lateral earth pressures by its weight or mass. The following types of retaining structures can be classified as gravity walls:

- Masonry and concrete walls
- Crib and bin walls
- Cantilever and counterfort walls
- Reinforced earth and geogrid walls

Each of these can be modified in a variety of ways to fit nearly any condition or requirement. The retaining structure should be designed by a qualified engineer.

Tiered Wall or Bench Plantings

These are alternatives to a low wall with face planting. They allows vegetation to be planted on slopes that would otherwise be too steep. Shrubs and trees planted on the benches screen the structure behind and lend a more natural appearance while their roots permeate and protect the benches.

Almost any type of retaining structure can be used in a tiered wall system. A tiered wall system provides numerous opportunities for use of vegetation on steep slopes and embankments.

Vegetated Cribwall

A cribwall is a structure formed by joining a number of cells together and filling them with soil, gravel, or rock to furnish strength and weight. A vegetated cribwall is filled with suitable backfill material and layers of live branch cuttings. The cuttings root inside the crib structure and extend into the slope. Once the live cuttings root and become established, the subsequent vegetation gradually takes over the structural functions of the wood members.

The cribwall provides immediate protection from erosion; while established vegetation provides longterm stability.

Where Practice Applies

This technique is appropriate at the base of a slope where a low wall may be required to stabilize the toe of the slope and reduce its steepness.

Not designed for or intended to resist large, lateral earth stresses. Recommended only to a maximum of 6 feet in overall height, including the excavation required for a stable foundation.

Useful where space is limited and a more vertical structure is required.

Should be tilted back or battered if the system is built on a smooth, evenly sloped surface.

May also be constructed in a stair-step fashion, with each successive course of timbers set back 6 to 9 inches toward the slope face from the previously installed course.

Construction Recommendations

Live material sizes

Live branch cuttings should be ½ to 2 inches in diameter and long enough to reach the back of the wooden crib structure.

Installation

Starting at the lowest point of the slope, excavate loose material 2 to 3 feet below the ground elevation until a stable foundation is reached.

Excavate the back of the stable foundation (closest to the slope) slightly deeper than the front to add stability to the structure.

Place the first course of logs or timbers at the front and back of the excavated foundation, approximately 4 to 5 feet apart and parallel to the slope contour.

Place the next course of logs or timbers at right angles (perpendicular to the slope) on top of the previous course to overhang the front and back of the previous course by 3 to 6 inches.

Each course of the live cribwall is placed in the same manner and nailed to the preceding course with nails or reinforcement bars.

When the cribwall structure reaches the existing ground elevation, place live branch cuttings on the backfill perpendicular to the slope; then cover the cuttings with backfill and compact.

Live branch cuttings should be placed at each course to the top of the cribwall structure with growing tips oriented toward the slope face. Follow each layer of branches with a layer of compacted soil to ensure soil contact with the live branch cuttings. Some of the basal ends of the live branch cuttings should reach to undisturbed soil at the back of the cribwall with growing tips protruding slightly beyond the front of the cribwall.

Vegetated Gabions

Empty gabions are placed in position, wired to adjoining gabions, filled with stones and then folded shut and wired at the ends and sides. Live branches are placed on each consecutive layer between the rockfilled baskets. These will take root inside the gabion baskets and in the soil behind the structures. In time the roots consolidate the structure and bind it to the slope.

Construction Recommendations

Live material sizes

Branches should range from ½ to 1 inch in diameter and must be long enough to reach beyond the back of the rock basket structure into the backfill.

Installation

Starting at the lowest point of the slope, excavate loose material 2 to 3 feet below the ground elevation until a stable foundation is reached.

Excavate the back of the stable foundation (closest to the slope) slightly deeper than the front to add stability to the structure. This will provide additional stability to the structure and ensure that the living branches root well.

Place the fabricated wire baskets in the bottom of the excavation and fill with rock.

Place backfill between and behind the wire baskets.

Place live branch cuttings on the wire baskets perpendicular to the slope with the growing tips oriented away from the slope and extending slightly beyond the gabions. The live cuttings must extend beyond the backs of the wire baskets into the fill material. Place soil over the cuttings and compact it.

Repeat the construction sequence until the structure reaches the required height.

Vegetated Rock Wall

Vegetated rock walls differ from conventional retaining structures in that they are placed against relatively undisturbed earth and are not intended to resist significant lateral earth pressures. A vegetated rock wall is a combination of rock and live branch cuttings used to stabilize and protect the toe of steep slopes.

This system is appropriate at the base of a slope where a low wall may be required to stabilize the toe of the slope and reduce its steepness.

Construction Recommendations

Live material sizes

Live cuttings should have a diameter of ½ to 1-inch and be long enough to reach beyond the rock structure into the fill or undisturbed soil behind.

Inert materials

Inert materials consist of rocks and fill material for the wall construction. Rock should normally range from 8 to 24 inches in diameter. Larger boulders should be used for the base.

Installation

Starting at the lowest point of the slope, remove loose soil until a stable base is reached. This usually occurs 2 to 3 feet below ground elevation. Excavate the back of the stable foundation (closest to the slope) slightly deeper than the front to add stability to the structure.

Excavate the minimum amount from the existing slope to provide a suitable recess for the wall.

Provide a well-drained base in locations subject to deep frost penetration.

Place rocks with at least a three-point bearing on the foundation material or underlying rock course. They should also be placed so that their center of gravity is as low as possible, with their long axis slanting inward toward the slope if possible.

When a rock wall is constructed adjacent to an impervious surface, place a drainage system at the back of the foundation and outside toe of the wall to provide an appropriate drainage outlet.

Overall height of the rock wall, including the footing, should not exceed 5 feet.

A wall can be constructed with a sloping bench behind it to provide a base on which live branch cuttings can be placed during construction. Live branch cuttings should also be tamped or placed into the openings of the rock wall during or after construction. The butt ends of the branches should extend into the backfill or undisturbed soil behind the wall.

The live branch cuttings should be oriented perpendicular to the slope contour with growing tips protruding slightly from the finished rock wall face.

Joint Planting

Joint planting or vegetated riprap involves tamping live cuttings of rootable plant material into soil between the joints or open spaces in rocks that have previously been placed on a slope. Alternatively, the cuttings can be tamped into place at the same time that rock is being placed on the slope face.

Roots improve drainage by removing soil moisture. Over time, they create a living root mat in the soil base upon which the rock has been placed. The root systems of this mat help to bind or reinforce the soil and to prevent washout of fines between and below the rock units.

Construction Recommendations

Live material sizes

The cuttings must have side branches removed and bark intact. They should range in diameter from ½ inch to 1 ½ inches and be sufficiently long to extend into soil below the rock surface.

Installation

Tamp live branch cuttings into the openings of the rock during or after construction. The butt ends of the branches should extend into the backfill or undisturbed soil behind the riprap.

Orient the live branch cuttings perpendicular to the slope with growing tips protruding slightly from the finished face of the rock.

Slope Stabilization

Bioengineering techniques for slope stabilization involve using a combination of vegetative and mechanical measures on steep slopes, cut and fill banks, and unstable soil conditions that cannot be stabilized using ordinary vegetative techniques.

Advantages

Vegetation reduces sheet erosion on slopes and impedes sediment at the toe of the slope.

Where soils are unstable and liable to slip due to wet conditions, utilization of soil moisture by vegetation can reduce the problem.

Shrubs and trees shelter slopes against the impact of rainstorms, and the humus formed by decaying leaves further helps to impede runoff.

Mechanical measures help to stabilize soil long enough to allow vegetation to become established.

Disadvantages/Problems

The planting of non-seeded material such as live willow brush is a specialized operation and cannot be highly mechanized or installed by unskilled labor.

The methods described are effective but require familiarity with soils, hydrology, and other physical data to design measures that will solve the problem.

Design and Construction Recommendations

The following bioengineering methods can be used after slopes have been protected by diversion of runoff.

Sod walls or retaining banks

These may be used to stabilize terraces. Sod is piled by tilting it slightly toward the slope and should be backfilled with soil and compacted as they are built up. Sod walls can be as steep as 1: 8 but should not be higher than 5 feet.

Timber frame stabilization

This can be effective on gradients up to 1:1. The following steps are involved in construction:

- Lay soil retarding frames of 2 x 4 in. vertical members and 1 x 4 in. horizontal members on slopes. Frames on slopes over 15 feet in length need to be anchored to slope to prevent buckling.
- Attach 14 gauge galvanized wires for anchoring wire mesh.
- Fill frames with moist topsoil and compact the soil.
- Spread straw 6 inches deep over slope.
- Cover straw with 14 gauge 4-inch mesh galvanized reinforced wire.

- Secure wire mesh at least 6 feet back of top slope.
- Plant ground cover plants through straw into topsoil.

Woven willow whips

May be used to form live barriers for immediate erosion control.
Construction:

- Three-foot poles are spaced at 5 foot distances and driven into the slope to a depth of 2 feet.
- Two-foot willow sticks are inserted between poles at one foot distances.
- Live willow branches 5 feet long are sunk to a depth of 1 inch and interwoven with poles and stocks.
- Spaces between the woven "fences" are filled with topsoil. Fences are generally arranged parallel to the slope or in a grid pattern diagonal to the direction of the slope.

Streambank Stabilization

Often channel reaches can be made stable by establishing vegetation where erosion potential is low and installing structural measures, or a combination of vegetative and structural measures on more vulnerable areas; such as the outside of channel bends and where the natural grade steepens.

Any work in or adjacent to a stream should be coordinated with the local Conservation Commission, and done in accordance with wetlands protection laws.

Advantages

Bioengineering techniques are generally less costly than structural practices and more compatible with natural stream characteristics.

Roots and rhizomes stabilize streambanks.

Certain reeds and bulrushes have the capability of improving water quality by absorbing certain pollutants such as heavy metals, detergents, etc.

Plants regenerate themselves and adapt to changing natural situations, thus offering a distinct economic advantage over mechanical stabilization.

Mechanical materials provide for interim and immediate stabilization until vegetation takes over.

Once established, vegetation can outlast mechanical structures and requires little maintenance while regenerating itself.

Aesthetic benefits and improved wildlife and fisheries habitat.

Disadvantages/Problems

Native plants may not be carried by regular nurseries and may need to be collected by hand, or obtained from specialty nurseries. Nurseries which carry these plants may require a long lead time for large orders.

Flow retarding aspects of vegetated waterways need to be taken into account.

Planning Considerations

Streambanks can be divided into:

- Aquatic plant zones, at the mean low-water level;
- Reed bank zones, covered at bankfull stage;
- Lower riparian zones or open floodway zones naturally covered with willows and shrubbery plants;
- Upper riparian areas or flood fringe areas that would naturally be covered with canopy-forming trees.

Aquatic plant zones

Aquatic plants are often considered weeds and a nuisance, though they do slow down streamflow and protect the streambed. Primary emphasis of streambank stabilization lies in the bankfull zone.

Reed bank zone

The reed bank zone forms a permeable obstacle, slowing down current waves by friction. Plant shoots, with a root clump, can be planted in pits at ½ to 1 foot depth below water, or in a reed roll.

Lower riparian zone

Lower riparian zones often have a natural growth of willow, alder, cottonwood, small maples, and various berries. These vegetative types can be reintroduced on denuded floodplains to stabilize the soil with their roots. In periods of high water, their upper branches reduce the speed of the current and thereby the erosive force of water. The most commonly used vegetative stabilizer is willow; because of its capability to develop secondary roots on cut trunks and to throw up suckers. Willows are planted either as individual cuttings bound together in various forms or wired together in fascines.

Slip banks of the lower riparian zone and tidal banks can be stabilized with grass. First the bank needs to be graded to a maximum slope of 3:1. Topsoil should be conserved for reuse; lime and fertilizer should be applied. Coarse grass and beach grass should be planted at the water's edge to trap drift sand; and bermuda grass, suitable for periodic inundation, should occupy the face of the slope, followed by tall fescue on higher ground.

In the lower riparian zone (open floodway) bank stabilization efforts should be concentrated on critical areas only. The stabilizing effect of riprap can be supplemented with willows which will bind soil through their roots and screen the bank. Banks can be paved with stone (set in sand).

Willow cuttings in joints need to be long enough to extend to natural soil and should have 2 to 4 buds above surface. Willow branches in riprap should be installed simultaneously.

Branches should extend 1 foot into the soil below stone and 1 ½ feet above ground, pointing downstream.

Bioengineering Techniques for Streambank Stabilization

Reed Roll

A trench 1- ½ feet wide and deep is dug behind a row of stakes; wire netting is then stretched from both sides between upright planks; coarse gravel is dumped on this and covered with reed clumps until the two edges of the netting can just be held together with wire. The upper edge of the roll should not be more than two inches above water level. The planks are then removed and gaps in the ditch are backfilled.

Reed Berm

Reed berms, consisting of a combination of reeds and riprap, break wave action and erosion of banks by currents. Banks should not exceed a 2:1 slope. Riprap is placed to form a berm that extends beyond the surface at mean low-water level, separating the reed bed from the body of water.

Fascines

Packed fascine-work can be employed on cut banks. It consists of one foot layers of branches covered with young, freshly cut shoots secured by stakes. The spaces between the shoots are filled with dirt and another layer is added on top.

Brush-mesh

A variation is the brush-mesh technique, which is designed to stabilize breached cut banks and to encourage the deposition of sediment. It involves the following steps:

- Placement of poles at 10 foot distance.
- Placement of large branches and brush facing the stream.
- Setting cuttings of live willow branches between the brush vertically, and
- Securing vertical willows with cuttings set diagonally facing the streamflow.

Streams in urban settings may carry an increase in runoff of such great magnitude that they cannot be maintained in a natural state. Soil bioengineering methods can provide for stabilization more aesthetically and with higher effectiveness than purely mechanical techniques. This applies primarily to: the reed bank zone and the lower riparian zone.

The following techniques apply to the reed bank zone:

Willow Mattress

Willow mattresses are made from 4 to 6 foot willow switches set into six inch trenches and held down by stakes that are braided or wired together. The entire mattress is lightly covered with soil.

Willow Jetty

Willow jetties can be constructed at the water level to stabilize a cutbank by deflecting the current and by encouraging deposition of sediment.

- Dig ditches diagonally to direction of flow, and place fill to form berm downstream from ditch.
- Set 2-foot willow branches (4-foot may be needed) at 45 degree angle and 3-inch spacing facing downstream.
- Weigh down branches with riprap extending beyond water level.

Willow Gabions

Willow gabions can be used when a hard-edged effect is desired to deflect the eroding flow of water. Live willow branches, pointing downstream, are inserted through the wire mesh when the gabion is packed with stone and an addition of finer materials. Branches need to be long enough to extend through the gabion into the soil of the bank. They also should be placed at an angle back into the slope.

Piling revetment

Piling revetment with wire facings is suited for the stabilization of cutbanks with deep water. It involves the following steps:

- Drive heavy timbers (8-12 inch diameter) on 6 to 8-foot centers along bank to be protected to point of refusal or one half length of pile below maximum scour.
- Fasten heavy wire fencing to the post and if the streambed is subject to scour, extend it horizontally on the streambed for a distance equal to the anticipated depth of scour and weight with concrete blocks. As scour occurs, this section will drop into place.
- Pile brush on the bank side of the fence, and plant willow saplings on bank to encourage sediment deposits.

Willow Branch Mat Revetment

Willow branch mat revetment takes the following steps to install:

- Grade slope to approximately 2:1 and excavate a 3 foot ditch at the toe of slope.
- Lay live willow brush with butts upslope and anchor mat in the ditch below normal waterline by packing with large stones.
- Drive 3-foot willow stakes 2 ½ feet on center to hold down brush; connect stakes with No. 9 galvanized wire and cover brush slightly with dirt to encourage sprouting.

Maintenance

Under normal conditions, maintenance needs should be minor after the system is established. Maintenance generally consists of light pruning and removal of undesirable vegetation. Heavy pruning may be required to reduce competition for light or stimulate new growth in the project plantings.

A newly installed bioengineering project, however, will need periodic inspections until it is established. New vegetation is vulnerable to trampling, drought, grazing, nutrient deficiencies, toxins, and pests, and may require special attention at times.

In many situations, installed bioengineering systems become source sites for future harvesting operations. Selective removal of vegetation may be required to eliminate undesirable invading species. They should be cut out every 3 to 7 years.

More intensive maintenance may be needed to repair problem areas created by high intensity storms or other unusual conditions. Site washouts should be repaired immediately. Generally, reestablishment should take place for a one-year period following construction completion and consist of the following practices:

- Replacement of branches in dead unrooted sections
- Soil refilling, branchpacking, and compacting in rills and gullies
- Insect and disease control
- Weed control

Gullies, rills, or damaged sections should be repaired using of healthy, live branch cuttings; preferably installed during the dormant season. Use the branchpacking system for large breaks, and the live gully repair system for breaks up to 2 feet wide and 2 feet deep. If the dormant season has passed, consider using rooted stock.

Final Check

A final check should be made two years after the installation is completed. Healthy growing conditions (overall leaf development and rooted stems) should exist as follows:

Live stakes	70%-100% growing
Live fascines	20% - 50% growing
Live cribwall	30% - 60% growing
Brushlayers	40% - 70% growing
Branchpacking	40% - 70% growing
Live gully repair	30% - 50% growing
Vegetated rock wall	50% - 80% growing
Vegetated gabion	40% - 60% growing
Joint planting	50% - 70% growing

Growth should be continuous with no open spaces greater than 2 feet in linear systems. Spaces two feet or less will fill in without hampering the integrity of the installed living system.

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Herbaceous Plants for Streambank Soil Bioengineering Applications in Massachusetts

Native Plants Suited for Planting in Saturated Soils and/or Coir Geotextile1/:

Scientific Name	Common Name	Notes
Asclepias incarnata	Swamp milkweed	Peat plugs/pots.
Acorns calamus or antericanus	Sweet Flag	Plants in peat plugs/ pots or dormant rootcuttings.
Calamagrostis canadensis	Blue Joint Reed Grass	Peat plugs/pots. Can be seeded if no standing or flowing water.
Carex spp.	Sedges	Some native species are: comosa, crinita,intumescens, lurida, stricta and vulpanoidea.Peat plugs/pots or bare-rooted OK.
Cinna arundinacea	Wood Reed Grass	Peat plugs/pots. Can be seeded if nostanding or flowing water.
Distichlis spicata	Sea Shore Saltgrass	Peat plugs/pots. Coastal areasonly.
Eupatorium perfoliatum and E. purpureum	Boneset and Joe-Pye Weed	Peat plugs/pots.
Glyceria canadensisand G. striata	Manna Grasses	Peat plugs/pots or bare-rooted plants.Can be seeded if no standing or flowing water.
Iris versicolor	Blue Flag Iris	Dormant plants.
Juncus canadensis and J. effusus	Rushes	Peat plugs/pots or bare rooted plants.
Leersia oryzoides	Rice Cut Grass	Peat plugs/puts. Can be seeded if no standing or flowing water.

Pontederia cordata	Pickerel Weed	Peat pots or bare rooted plants.
Sagittaria latifolia	Arrowhead	Plant as tuber or in peat plug/put.
Scirpus spp.	Bulrushes	Some native species are: S.acutus, S.atrovirens, S. cyperinus, S. pungens, S. validus. Peat plugs or bare root plants.
Sparganium spp.	Bur Reed	S. americanum and S. eutycarpum are native species.
Spartina alterniflora	Salt Marsh Grasses	Peat plugs/pots. Plantings within proper tidal zone is critical.
Spartina pectinata	Fresh Water Cordgrass	Peat pots/pots.
Typa latifolia and T angustifolia	Cattails	Peat pots or bare root plants.
Verbena hastata	Blue Vervain	Peat plugs/pots.

Grasses Suited for Planting on Streambanks in Combination with Bioengineered Applications2/3/:

Name	Status	Application	Notes
Agrostis alba Red Top	Introduced	All bank zones	Cool Season.
Agrostis stolonifera, var. palustris Creeping/Marsh Bentgrass	Native statewide	Low to mid bank zone	Cool Season.
Ammophila breviligulata American Beachgrass	Native to coastal counties	Sandy, gravelly droughty bank	Cape cultivar is native to MA Use culms to establish
Andropogon gerardii Blue Bigstem	Native statewide	Droughty upper bank	Warm season
Andropogon virginicus Broomsedge	Native statewide except Berkshire and Franklin	Mid to upper bank zone	Warm season
Dichanthelium clandestinum Deertongue Grass	Native statewide	Mid to upper bank zone	Warm season.
Elymus canadensis Nodding Wild Rye	Native statewide	Mid to upper bank zone	Cool season.
Festuca rubra Red Fescue	Native away from coastal areas. Introduced to coast.	Mid to upper bank zone	Cool season. Shade tolerant
Lolium perenne Perennial Ryegrass	Introduced	Mid to upper bank zone	Cool season. Fast growing-short term.
Panicum virgatum Switchgrass	Native statewide	Mid to upper bank zone	Warm season.
Sorghastrum nutans Indiangrass	Native statewide	Mid to upper bank zone	Warm season
Schizachyrium scoparium Little Bluestem	Native Statewide	Upper bank zone	Warm season

Notes:

Bank Zones:

Lower is at or near the normal waterline to the upper limit of saturation due to capillary action.

Mid is the surface area above the upper limit of the lower zone to about 3 feet from the top of bank.

Upper is the surface area about 3 feet from the top of bank and extending into the riparian zone.

Seeding Periods:

Warm season grasses are seeded in spring up to June 1, or as a dormant seeding November - March.

Cool season grasses are seeded in spring up to June 1, or in late summer/ early fall August 15 - October.

1/ Table prepared by R. DeVergilio, Natural Resources Conservation Service, Amherst, MA., with technical input from M. Marcus, New England Wetland Plants, Inc., Amherst MA. Technical review by C. Miller, Plant Materials Specialist, NRCS, Somerset, NJ.

2/ Table prepared by R. DeVergilio, Natural Resources Conservation Service, Amherst, MA., with technical input from C. Miller, Plant Materials Specialist, NRCS, Somerset NJ.

3/ Grasses are usually seeded upon the bank or over a particular bioengineering application, however most species listed are also commercially available as rooted plants.

4/ Beachgrass is established by vegetative means only (planting of dormant culms).

Native plant review by The Massachusetts Native Plant Advisory Committee,1/29/96

Woody Plants for Streambank Soil Bioengineering Applications in Massachusetts

Name	Native	Size, Form	Plant Material Type 1/	Rooting Ability	Notes
Alnus rugosa/serrulata Speckled/Smooth Alder	State wide	Large Shrubs	Rooted Plants only	Poor	Good for low to mid bank zone
Aronia arbutifolia Red Chokecherry	Statewide	Shrub	Rooted Plants only	Poor	Good for low to mid bank zone
Baccharis halimifolia Eastern False Willow	Coast only	Med. Shrub	Facines Cuttings Rooted Plants	Good	Good for low to mid bank zone. Resistant to salt spray
Cephalanthus occidentalis Button Bush	Statewide	Med. Shrub	Layering Cuttings Rooted Plants	Good	Good for low bank zone. Prefers at least periodic inundation.
Clethera alnifolia Sweet Pepper Bush	Statewide	Med. Shrub	Rooted plants only	Poor	Good for mid-upper bank zone. Good for salt tolerance.
Cornus amomum Silky Dogwood	Statewide	Small Shrub	All	V. Good	Good for all bank zones. Tolerates shade.
Cornus racemosa Gray Dogwood	Statewide	Med. Shrub	All	Good	Good for mid-upper bank zone. Tolerates shade and drought.
Cornus sericea Red Osier Dogwood	W MA only 2/	Med. Shrub	All	V. Good	Good for all bank zones.
Ilex opaca American Holly	SE MA	Sm.Tree	Rooted Plant only	Poor	Good for upper bank zone. Shade and drought tolerant.
Ilex verticillata Winterberry Holly	Statewide	Med. Shrub	Rooted plant only	Poor	Mid to lower banks. Prefers seasonal flooding.
Lindera benzoin Spicebush	Statewide	Shrub	Rooted Plant only	Poor	All bank zones. Good shade tolerance.
Populus balsamifera Balsam Poplar	W. MA only 2/	Tree (see note)	All	V. Good	3/ Use cautiously on streambanks. Good for riparian zone.
Populus deltoides Eastern Cottonwood	W. MA only 2/	Tree (see note)	All	V. Good	3/ Use cautiously on streambank. Good for riparian zone.
Rhododendron viscosum	Statewide	Med. Shrub	Rooted Plant only	Poor	Good for mid- to lower bank zones

Woody Plants for Streambank Soil Bioengineering Applications in Massachusetts (Continued)

Name	Size, Native	Form	Plant Material Type 1	Rooting Ability	Notes
Rosa palustris Swamp Rose	Statewide	Sm. Shrub	Facines Rooted Plants	Good	Low-mid bank zone
Salix amygdaloides Peachleaf Willow	No-Introduced	Lg. Shrub	All	V.Good	Good for all bank zones
Salix discolor Pussy Willow	Statewide	Med. Shrub	All	V.Good	Good for all bank zones
Salix eriocephala Erect Willow	Statewide	Lg. Shrub	All, But no Brush Mattress	V.Good	Good for all bank zones.
Salix exigua Sandbar Willow	CT River Valley	Lg. Shrub	All	Good	Mid to lower bank zones
Salix nigra Black Willow	Statewide	Tree (see note)	All V.Good		3/ Use cautiously on streambank.Good for riparian zone.
Salix Humilis Prarie Willow	Statewide	Med. Shrub	All	Good	Good for bank zones
Salix pupurea Purpleosier Willow	No- (see note)	Lg. Shrub	All	V.Good	"Streamco"Cultivar released by NRCS. All bank zones
Salix x cottetii Dwarf Willow	No - (see note)	Sm. Shrub	All	V.Good	"Bankers" cultivar released by NRCS. Low to mid-bank zones
Sambucus canadensis American Elderberry	Statewide	Sm. Shrub	Facines Cuttings	Good	Good for mid-bank zone. Use with other good rooting species only.
Spirea tomentosa Steeple Bush	Statewide	Sm. Shrub	Layering	Poor-Fair	Mid to upper bank.Use with other good rooting species only.
Virburnum dentatum Southern Arrowood	South and East	Med. Shrub	Rooted Cuttings and plants	Fair	Good for mid-bank zone
Virburnum recognitum Northern Arrowood	North and West	Med. Shrub	Rooted plants	Poor	Good for all bank zones. Rooted cuttings good.
Virburnum trilobum 4/ American Cranberry Bush	Yes, but not Cape and islands	Med. Shrub	Rooted Plants	Poor	Good for all bank zones. Good shade tolerance.
Virburnum lentago Nannyberry	Yes, but not Cape and Islands	Lg. Shrub	Facines, Stakes	Fair	Tolerates shade, good for mid-bank. Use with other good rooting species only.

Notes:
Table prepared by R. DeVergilio, Natural Resources Conservation Service, Amherst MA. Adapted from NRCS data base 'Plants For BioEngineering, Uses, H. W. Everett, 11/95'. Native plant review by the Massachusetts Native Plant Advisory Committee.

Special Note...... 'Streamco' and 'Bankers' are not native to Massachusetts. It is recommended they only be used in combination with native species.

1/ Plant Material Types: 'All' includes Dormant Fascines, Stakes, Brush Mattresses, Layering, and Cuttings as well as Rooted Cuttings and Plants.

2/ Western Mass. includes Berkshire, Franklin, Hampshire, and Hampden Counties.

3/ Tree species, such as cottonwood, poplar and black willow, are recommended for riparian area plantings and are not recommended for establishment upon the streambank itself due to potential for windthrow at maturity, and subsequent damage to the streambank.

4/ *Viburnum opulus* is similar to *V.trilobum* and is often confused with it. *V. opulus* is introduced to Massachusetts.

Streambank Zones:

Lower is at or near the normal waterline to the upper limit of saturation due to capillary action.

Mid is the surface area above the upper limit of the lower zone to about 3 feet from the top of bank.

Upper is the surface area about 3 feet from the top of bank and extending into the riparian zone.

Erosion and Sediment Control Best Management Practices for Individual Homesites and Small Parcels

Construction on small developments can cause large amounts of sediment to be transported to receiving waters. The following are some of the damaging activities and conditions that may occur during development:

Exposed and unprotected soil is often left throughout the development. When runoff occurs, sediment is transported into the nearest stormwater facility or stream, eventually clogging it.

Vehicles and heavy equipment track soil from the development onto the street. Gullies formed by tire tracks become channels for runoff flow.

Vegetation bordering streams or lakes is often removed during construction. This increases the water temperature by removing shade. An increase in water temperature can contribute to algae blooms and may change the species composition of the lake or stream. Because the vegetation has been removed, there is no barrier to prevent sediment from entering the stream. This can clog spawning grounds and fish gills.

These problems may occur during work performed by subcontractors who are on-site for a very short time. Cooperation and communication between developers, builders, and subcontractors are essential to minimize erosion and damage to the environment.

Clearing and Grading

Plan and implement proper clearing and grading of the site. It is important to clear only the areas needed, thus keeping exposed areas to a minimum. Phase the clearing so that only those areas that are actively being worked are uncovered. Clearing limits should be flagged prior to the start of clearing work.

Excavated Basement Soil

Locate excavated basement soil a reasonable distance behind the curb, such as in the backyard or side yard area. This will increase the distance eroded soil must travel to reach the storm sewer system. Soil piles should be covered until the soil is either used or removed. Piles should be situated so that sediment does not run into the street or adjoining yards.

Backfilling

Backfill basement walls as soon as possible and rough grade the lot. This will eliminate large soil mounds which are highly erodible and prepares the lot for temporary cover which will further reduce erosion potential.

Removal of Excess Soil

Remove excess soil from the site as soon as possible after backfilling. This will eliminate any sediment loss from surplus fill.

Management Of Soil Banks

If a lot has a soil bank higher than the curb, a trench or berm should be installed moving the bank several feet behind the curb. This will reduce the occurrence of gully and rill erosion while providing a storage and settling area for stormwater.

Construction Road Access

Apply gravel or crushed rock to the driveway area and restrict truck traffic to this one route. Driveway paving can be installed directly over the gravel. This measure will eliminate soil from adhering to tires and stops soil from washing into the street. This measure requires periodic inspection and maintenance including washing, top-dressing with additional stone, reworking and compaction.

Soil Stabilization

Stabilize denuded areas of the site by mulching, seeding, planting, or sodding.

Street Cleaning

Provide for periodic street cleaning to remove any sediment that may have been tracked out. Sediment should be removed by shovelling or sweeping and carefully removed to a suitable disposal area where it will not be re-eroded.

References

Lobdell, Raymond, ***A Guide to Developing and Re-Developing Shoreland Property in New Hampshire***, North Country Resource Conservation and Development Area, Inc., Meredith, NH, 1994.

Minnesota Pollution Control Agency, Division of Water Quality, ***Protecting Water Qualily in Urban Areas, Best Management Practices for Minnesota***, MN, October, 1989.

Washington State Department of Ecology, ***Stormwater Management Manual for the Puget Sound Basin***, Olympia, WA, February, 1992.

Erosion and Sediment Control Best Management Practices for Sand and Gravel Pits

Erosion from sand and gravel pits can contribute a large amount of sediment to adjacent water courses. Sand and gravel also provides a very porous medium for transporting soluble pollutants to the underlying groundwater. Many sand and gravel operations are located within or near the recharge area of public and private wells. A major threat to groundwater exists when excavation activities take place in these areas. Exposure of the saturated zone in recharge areas can leave groundwater resources vulnerable to contamination because it decreases filtering. An added problem is that abandoned excavation pits have been used for the unregulated disposal of solid and liquid wastes and salt-laden snow. The information in this section was adapted from *Resource Extraction, Guidelines for Sand and Gravel Pits*, in Chapter Four of the *Massachusetts Nonpoint Source Management Manual*, *Appendix D, Vegetating New Hampshire Sand and Gravel Pits*, in *Stormwater Management and Erosion Control for Urban and Developing Areas in New Hampshire*, and *Revegetating Sand and Gravel Pits in the Northeast States* by Dickerson, Kelsey, Godfrey, Gaffney, and Miller.

Soil erosion, aesthetics, and adverse impacts on water quality are concerns associated with the operation, maintenance, and closure of sand and gravel pits. A good vegetative cover of grasses and legumes can alleviate these concerns. Vegetative cover will retard surface runoff and prevent erosion, reducing the sedimentation of nearby streams, waterways, and waterbodies. Vegetative cover will enhance the aesthetics of sand and gravel pits while providing nesting and escape cover for wildlife.

Controlling the removal of soil in recharge areas is a commonly used technique to minimize groundwater impacts. Many municipalities statewide have adopted earth removal bylaws which limit excavation within varied distances to the water table (ranging from 4 feet to 10 feet). When regulating excavation activities, the seasonal and annual fluctuations in the water table should be considered. To insure maximum groundwater protection, local controls should be designed to incorporate more conservative groundwater table estimates.

Massachusetts law (310 CMR 22.21 (2) (b) 6) prohibits the removal of soil, loam, sand, gravel or other mineral substance within 4 feet of the historical high groundwater table elevation. The regulations do allow for removal of soil provided the same soil is replaced at a final grade greater than 4 feet above the historical high water mark within 45 days. This is intended to facilitate necessary, short term excavation/soil movement activities while insuring that sand and gravel deposits associated with favorable groundwater areas are not replaced with materials of poorer quality. Building foundations and utility work are also given exemptions under this provision.

Sand and gravel pits are difficult sites to permanently vegetate. The difficulty is due to droughty conditions, low soil organic matter, low soil fertility, and lack of topsoil. Stockpiling topsoil can greatly reduce the difficulty of establishing vegetation. Most town by-laws prohibit selling topsoil. A 4-inch cap of topsoil will usually be sufficient for establishing selected vegetation that is otherwise compatible with the site condition.

Recommendations for sand and gravel pit operation.

Information Needed For Developing A Stabilization Plan

Topography for the "original ground surface" based on no greater than five-foot contour intervals (2 foot contour levels should be provided whenever possible).

Log of soil borings taken to the depth of the proposed excavation. The number of borings taken will vary with the size and geological make-up of the site.

Topographical map showing planned final grades, drainage facilities, etc. after excavation.

Operation Standards

No excavation should be closer than 200 feet to an existing public way unless specifically permitted by authorized official. No excavation should approach neighboring lot lines closer than 50 feet. (No excavation closer than 50 feet.) Natural vegetation should be left and maintained on the undisturbed land for screening and noise reduction purposes.

All loaded vehicles should be suitably covered to prevent dust and contents from spilling and blowing from the load.

The active gravel removal operation area should not exceed a total area of three acres at any one time.

All access roads leading to public ways should be treated with stone, or other suitable material to reduce dust and mud for a distance of 200 feet back from said public way; unless there is a stabilized construction entrance/tire wash at points of vehicular ingress/egress. Any spillage on public ways should be cleaned up by the operator.

Access roads should be constructed at an angle to the public way or constructed with a curve so as to help screen the operation from public view.

Most communities limit gravel removal close to the seasonal high water table; usually a range of 2 to 10 feet above seasonal high water table. This elevation should be established from test pits or soil borings and the level related to a permanent monument on the property. This information should show on the topographic plan.

During operations, when an excavation is located closer than 200 feet from a residential area or public way and where the excavation will have a depth of more than 15 feet with a slope in excess of 1: 1, a fence at least four feet high should be erected to limit access to this area.

No area should be excavated so as to cause accumulation of free standing water. Permanent drainage should be provided as needed in accordance with good construction practices. Drainage should not lead directly into streams or ponds.

All topsoil and subsoil should be stripped from the operation area and stockpiled for use in restoring the area after the removal operation has ceased.

No excavation should be allowed closer than 100 feet from a natural stream.

Restoration Standards

Slopes should be left no steeper than 3:1; to provide stability and facilitate seeding efforts.

Avoid long slopes to help prevent erosion and to allow access for seeding, mulching, and maintenance. Control slope length by installing one terrace (10 feet wide and sloped into the cut slope) for every 40 vertical feet.

All debris, stumps, boulders, etc., should be removed from the site and disposed of in an approved location, or in the case of inorganic material, buried and covered with a minimum of two feet of soil.

Following excavation and as soon as possible thereafter, ground levels and grades should be established as shown on the completed topographical plan.

Construct diversions at tops of slopes to divert runoff water away from the slope banks to a stable outlet.

Construct rock lined chutes or equivalent to conduct concentrated flow of water to stable outlets.

Remove large stones, boulders, and other debris that will hinder the seeding process and the establishment of vegetation.

Spread a minimum depth of 4 inches of topsoil over the site, if available. Supplement as necessary with subsoil retained from. pit operations.

Retained subsoil and topsoil should be respread over the disturbed area to a minimum depth of four inches. Seed with a grass or legume mixture designed for the specific site. (Recommendations follow.)

Trees or shrubs should be planted to provide screening, natural beauty, and erosion control during the establishment period.

Upon completion of the operation, the land should be left so that natural storm drainage leaves the property within the original watercourses that existed prior to construction. The rate and volume of surface water runoff should not be increased as a result of the excavation operations.

Obtain soil samples by collecting 6 to 8 small samples (one or two handfuls each) of soil material from the upper 4 inches of the area to be seeded. Mix the small samples to obtain one composite sample.

Use part of the sample for a soil test to determine lime and fertilizer needs. Run the balance of the sample(s) through a sieve analysis to determine the percent by weight passing a No. 200 sieve. Those passing are called "fines."

If no soil tests are made, soil can be treated with three tons of lime per acre and 1,000 pounds of 10-10-10 fertilizer per acre. Basing lime and fertilizer recommendations on actual soil tests is preferable, however, and will result in much better long-term vegetative performance.

Planting Procedures

Species and Variety Selection

Select a grass/legume mix (see chart following) based on the percent weight passing a No. 200 sieve as outlined above. The standard conservation mixes available from local seed suppliers are not recommended on droughty sites. These mixes usually provide a green cover very quickly, but the plant species begin to die in two to four years on sterile and droughty sites.

Where percent by weight passing a No. 200 sieve is less than 15, select options from Mix 1.

Mix 2 is recommended if suppression of woody growth is desired and there is more than 15 percent by weight passing a No. 200 sieve.

Where percent by weight passing a No. 200 sieve is between 15 and 20, use Mix 1 or 2. Where percent by weight passing a No. 200 sieve is above 20, use Mix 1, 2, or 3.

Lime and Fertilizer Determination

Mix 1 - If soil test data is not available, lime at the rate of 1 ton/acre (50 lbs/1,000 sq ft). Fertilize with 500 lbs/acre (11 lbs/1,000 sq ft) of 10-20-20 or equivalent. Incorporate lime, fertilizer, and seed using rakes if seeding is done by hand. It is highly recommended to use a bulldozer to "track" the site after seeding. Tracking will incorporate the lime, fertilizer, and seed to promote seed germination.

Mix 2 - In lieu of a soil test, lime at the rate of 2 tons/acre (90 lbs/1,000 sq ft). Fertilize with 500 lbs/acre (11 lbs/1,000 sq ft) of 1020-20 or equivalent.

The seed needs to be incorporated into the soil to ensure success and to shorten establishment time. This is most critical for the large seeded legumes in Mix 2. On the flatter slopes, use a bulldozer to "track in" the seed.

Mix 1. Warm season grasses.

Species	Varieties, listed in preferential order (select one)	Options for various Situations (1) Lbs Per Acre (PLS)		
		(2)	(3)	(4)
Switchgrass	Trailblazer, Pathfinder	6	2	6
Big Bluestem	Niagara, Kaw	4	2	4
Little Bluestem	Aldous, Camper, Blaze	2		
Deertongue Grass			— 5-10 —	
Indian Grass			— 5-10 —	

Notes:
(1) Warm season grass seed is sold and planted on the basis of pure live seeds (PLS). An adjustment is made to the bulk pounds of seed to compensate for inert material and dead seed.
(2) This combination most closely represents the naturally occurring vegetation where warm season grasses are native in the northeast.
(3) This combination has the fastest establishment and cover.
(4) This combination is the simplest and may be easier to obtain. Options 2 or 1, however, will produce better results.

Mix 2. Legumes and cool season grass.

Species	Varieties, listed in preferential order (select one)	Lbs Per Acre
Flatpea (1)	Lathco	10
Perennial pea (1)	Lancer	10
Perennial Ryegrass		10
Tall fescue	Ky-31, Rebel, Ken-Hi	10
Red Top		1

Notes:
(1) These legumes must be inoculated at time of seeding. If seeding by hand, use a sticking agent, such as cola or milk to stick inoculant to seed. If seeding with hydroseeder, use 4 times the recommended rate of inoculant.

Mulch Determination for Hydro and Hand Seeding

Mulching for Mix 1

Use weed-free mulch. Clean straw is recommended. Mulch at the maximum rate of 500-700 lbs/acre. Higher mulching rates and mulch with weed seed content will inhibit seeding success significantly. If the erosion hazard is low and the seed is incorporated, mulching is not necessary for seeding success. Do not apply mulch prior to tracking with a bulldozer.

Mulching for Mix 2

Mulch with weed-free hay or straw and mulch at the rate of 2-3 tons/acre. The higher mulching rate is recommended where seed incorporation is difficult.

Seeding Methods

Alternative 1 - Large areas and/or steep slopes

Apply lime, seed, and fertilizer with a hydroseeder and, depending on the consistency of the soil material, steepness of slope, and seed mixture used:

- Press the seed into the soil by tracking with a bulldozer, or
- Cover the seed by walking back and forth over steep loose sandy slopes, or
- Apply mulch and a tackifier to hold the mulch in place.

Alternative 2 - Flat to gently sloping areas

(2:1 slopes maximum) Apply lime, seed, and fertilizer using farm type spreaders, and track the site with a bulldozer or apply mulch according to the circumstances.

Alternative 3 - Small areas

Apply lime, seed, and fertilizer by hand and rake.

Seeding Dates

Best seeding period is between snow melts in the spring and ends May 15. Early seeding is very important, especially for Mix 1. Actual seeding date depends on weather conditions, but substantial failure can be expected if seeding is done late.

Late summer and early fall seedings are not recommended. If late season seedings are necessary, they should be done after October 20 to prevent fall germination and subsequent winterkill.

Response of Seeding

The plant species in Mixes 1 and 2 germinate and grow slowly. Complete cover may not occur for 2-4 years. A well established stand, however, will last for years.

Follow-up seeding may be needed to establish vegetation on the more difficult parts of some sites. The need to do follow-up seeding can be determined the year after the initial planting.

Maintenance

Substantial stand vigor can be achieved if the site is topdressed with fertilizer one year after planting. If topdressing Mix 1, fertilize between June 15 and July 15. The timing of this topdressing, is important. Mixes 2 should be topdressed in the early spring.

Topdress Mixes 1 with a balanced fertilizer, applying 50 lbs of nitrogen/acre. For example, apply 250 lbs of 20-20-20/acre.

Topdress Mix 2 with 500 lbs of 0-20-20/acre in April, May, or June.

If mowing is desired to suppress woody growth, mow Mix 1 about mid-July leaving a stubble height of 6-8 inches. It is not necessary to mow Mix 2. A good cover of flatpea will prevent invasion of woody species.

References

Dickerson, John A., Kelsey, T. L., Godfrey, R. G., Gaffney, F. B., Miller, C., *Revegetating Sand and Gravel Pits in the Northeast States*, ____.

Massachusetts Department of Environmental Protection, Office of Watershed Management, Nonpoint Source Program, Massachusetts *Nonpoint Source Management Manual*, Boston, Massachusetts, June, 1993.

Minnick, E. L., and H. T. Marshall, *Stormwater Management and Erosion Control for Urban and Developing Areas in New Hampshire*, Rockingham County Conservation District, August 1992.

A Sample Erosion and Sedimentation Control Plan

This sample plan is for instructive purposes only. The specific number of maps, practices, drawings, specifications, and calculations required depends on the size and complexity of the development. The designer should select the most practical and efficient practices to control erosion and prevent sediment from leaving the site. The plan should be organized and presented in a clear, concise manner. Sufficient design and background information should be included to facilitate review. Construction details should be precise and clear for use by an experienced general contractor.

Due to size and space limitations, the following sections of the erosion and sedimentation control plan have not been included with this sample: vicinity map, site topography map, site development plan, erosion and sedimentation control plan drawing, detail drawings and specifications for the selected practices, vegetation plan, and supporting calculations.

Sample

EROSION AND SEDIMENTATION CONTROL PLAN ABC
INDUSTRIES, INC.
ANYTOWN, MASSACHUSETTS

JULY 1995

Table of Contents

Narrative

Project Description

The purpose of the project is to construct two large commercial buildings with associated paved roads and parking area. Another building will be added in the future. Approximately 6 acres will be disturbed during this construction period. The site consists of a total of 11.1 acres and is located in ANYTOWN, Massachusetts.

Site Description

The site has rolling topography with slopes generally 4 to 6 percent. Slopes steeper to 10 to 20 percent in the northwest portion of the property where a small healed-over gully serves as the principal drainageway for the site. The site is now covered with woody vegetation, predominantly white pines, 15 to 20 feet high. There is no evidence of significant erosion under present site conditions. The old drainage gully indicates severe erosion potential and receives flow from 5 acres of woods off-site. There is one large oak tree, located in the western central portion of the property, and a buffer area, fronting Terri Road, that will be protected during construction.

Adjacent Property

Land use in the vicinity is commercial/industrial. The land immediately to the west and south has been developed for industrial use. Areas to the north and east are undeveloped and heavily wooded, primarily in white pine. Hocutt Creek, the off-site outlet for runoff discharge, is presently a well stabilized, gently-flowing perennial stream. Sediment control measures will be taken to prevent damage to Hocutt Creek. Approximately 5 acres of wooded area to the east contribute runoff into the construction area.

Soils

The soil in the project area is mapped as Paxton (see Natural Resources Conservation Service, soil survey for your town) fine sandy loam in B and C slope classes. Paxton soils are considered moderately well to somewhat poorly drained with permeability rates greater than 6 inches/hour at the surface but less than 0.1 inches/hour in the subsoil. The subsurface is pale brown sandy loam, 6 inches thick. The subsoil consists of a pale brown and brownish yellow sandy clay loam ranging to light gray clay, 36 inches thick. Below 36 inches is a layer of fine sandy loam to 77 inches. The soil erodibility (K factor; see soil survey for an explanation) ranges from 0.20 at the surface to 0.37 in the subsoil.

Due to the slow permeability of the subsoil that will be exposed during grading, a surface wetness problem with high runoff is anticipated following significant rainfall events. No groundwater problem is expected. The tight clay in the subsoil will make vegetation difficult to establish. Some topsoil exists on-site and will be stockpiled for landscaping.

Planned Erosion and Sedimentation Control Practices

Sediment Basin

A sediment basin will be constructed in the northwest corner of the property. All water from disturbed areas, about 6 acres, will be directed to the basin before leaving the site. (NOTE: The undisturbed areas to the east and north could have been diverted, but this was not proposed because it would have required clearing to the property line to build the diversion and the required outlet structure.)

Construction Entrance

A temporary gravel construction entrance will be installed near the north-west corner of the property. During wet weather it may be necessary to wash vehicle tires at this location. The entrance will be graded so that runoff water will be directed to an inlet protection structure and away from the steep fill area to the north.

Block and Gravel Inlet Protection

A temporary block and gravel inlet protection device will be installed at the drop inlet located on the south side of the construction entrance. Runoff from the device will be directed into the sediment basin. (NOTE: The presence of this device reduces the sediment load on the sediment basin and provides sediment protection for the pipe. In addition, sediment removal at this point is more convenient than from the basin.)

Temporary Diversions

Temporary diversions will be constructed above the 3:1 cut slopes south of Buildings A and B to prevent surface runoff from eroding these banks. (NOTE: Sediment-free water may be diverted away from the project sediment basin.) A temporary diversion will be constructed near the middle of the disturbed area to break up this long, potentially erosive slope should the grading operation be temporarily discontinued. A temporary diversion will be constructed along the top edge of the fill slope at the end of each day during the filling operation to protect the fill slope. This temporary diversion will outlet to the existing undisturbed channel near the north edge of the construction site and/or to the temporary inlet protection device at the construction entrance as the fill elevation increases.

Level Spreader

A level spreader will serve as the outlet for the diversion east of Building A and south of Building B. The area below the spreader is relatively smooth and heavily vegetated with a slope of approximately 4 percent.

Tree Preservation and Protection

A minimum 2 foot high protective fence will be erected around the large oak tree at the dripline to prevent damage during construction. Sediment fence materials may be used for this purpose.

Land Grading

Heavy grading will be required on approximately 6 acres. The flatter slope after grading will reduce the overall erosion potential of the site. The buildings will be located on the higher cut areas, and the access road and open landscaped areas will be located on fill areas.

All cut slopes will be 3:1 or flatter to avoid instability due to wetness, provide fill material, give an open area around the buildings, and allow vegetated slopes to be mowed. Cut slopes will be fine graded immediately after rough grading; the surface will be disked and vegetated according to the Vegetation Plan.

Fill slopes will be 2:1 with fill depths as much as 12 to 15 feet. Fill will be placed in layers not to exceed 9 inches in depth and compacted.

The fill slope in the north portion of the property is the most vulnerable area to erosion on the site. Temporary diversions will be maintained at the top of this fill slope at all times, and the filling operation will be graded to prevent overflow to the north. Filling will be done as a continuous operation until final grade is reached.

The paved road located on the fill will be sloped to the south and will function as a permanent diversion. The area adjacent to the roads and parking area will be graded to conduct runoff to the road culverts. Runoff water from the buildings will be guttered to the vegetated channels. The finished slope face to the north will not be back-bladed. The top 2 to 6 inches will be left in a loose and roughened condition. Plantings will be protected with mulch, as specified in the Vegetation Plan.

A minimum 15 foot undisturbed buffer will be maintained around the perimeter of the disturbed area. (NOTE: This will reduce water and wind erosion, help contain sediment, reduce dust, and reduce final landscaping costs.)

Temporary Sediment Trap

A small sediment trap will be constructed at the intersection of the existing road ditch and channel number 3 to protect the road ditch. Approximately 2 acres of disturbed area will drain into this trap.

Sediment Fence

A sediment fence will be constructed around the topsoil stockpile and along the channel berm adjacent to the deep cut area, as necessary to prevent sediment from entering the channels.

Sod Drop Inlet Protection

Permanent sod drop inlet protection will replace the temporary block and gravel structure when the contributing drainage area has been permanently seeded and mulched.

Grassed Waterway

Grassed waterways with temporary straw-net liners will be constructed around Buildings A and B to collect and convey site water to the project's sediment basin.

Should the disturbed areas adjoining the channels not be stabilized at the time the channels are vegetated, a sediment fence will be installed adjacent to the channel to prevent channel siltation.

Riprap-Lined Waterways

A riprap channel will be constructed in the old gully along the north side of the property starting in the northwest corner after all other construction is complete. This channel will replace the old gully as the principal outlet from the site.

Construction Road Stabilization

As soon as final grade is reached on the entrance road, the subgrade will be sloped to drain to the south and stabilized with a 6 inch course of ¾ inch stone. The parking area and its entrance road will also be stabilized with ¾ inch stone to prevent erosion and dust during the construction of the buildings and prior to paving.

Outlet Stabilization

A riprap apron will be located at the outlet of the three culverts to prevent scour.

Surface Roughening

The 3:1 cut slopes will be lightly roughened by disking just prior to vegetating, and the surface 4 to 6 inches of the 2:1 fill slopes will be left in a loose condition and grooved on the contour.

Surface stabilization

Surface stabilization will be accomplished with vegetation and mulch as specified in the Vegetation Plan. One large oak tree southwest of Building A and a buffer area between the parking lot and Terri Road will be preserved. Roadway and parking lot base courses will be installed as soon as finished grade is reached.

Dust control

Dust control is not expected to be a problem due to the small area of exposure, the undisturbed perimeter of trees around the site, and the relatively short time of exposure (not to exceed 9 months). Should excessive dust be generated, it will be controlled by sprinkling.

Construction Schedule

1. Obtain plan approval and other applicable permits.
2. Flag the work limits and mark the oak tree and buffer area for protection.
3. Hold a pre-construction conference at least one week prior to starting construction.
4. Install the sediment basin as the first construction activity.
5. Install the storm drain with the block and gravel inlet protection at the construction entrance/exit.
6. Install the temporary gravel construction entrance/exit.
7. Construct the temporary diversions above the proposed building sites. Install the level spreader and sediment trap and vegetate disturbed areas.
8. Complete site clearing except for the old gully in the northwest portion of the site. This area will be cleared during the last construction phase for the installation of the riprap channel.
9. Clear the waste disposal area in the northeast corner of the property, only as needed.
10. Rough grade site, stockpile topsoil, construct channels, install culverts and outlet protection, and install sediment fence as needed. Maintain diversions along the top of the fill slope daily.
11. Finish the slopes around the buildings as soon as rough grading is complete. Leave the surface slightly roughened and vegetate and mulch as soon as possible.
12. Complete the final grading for roads and parking and stabilize with gravel.
13. Complete the final grading for the buildings.
14. Complete the final grading of grounds, topsoil critical areas, and permanently vegetate, landscape, and mulch.
15. Install the riprap outlet channel and extend riprap to pipe outlet under entrance road.
16. After the site is stabilized, remove all temporary measures and install permanent vegetation on the disturbed areas.
17. Estimated time before final stabilization is 9 months.

Maintenance Plan

1. All erosion and sediment control practices will be checked for stability and operation following every runoff-producing rainfall but in no case less than once every week. Any needed repairs will be made immediately to maintain all practices as designed.
2. The sediment basin will be cleaned out when the level of sediment reaches 2 feet below the top of the riser. Gravel will be cleaned or replaced when the sediment pool no longer drains properly.
3. Sediment will be removed from the sediment trap and block and gravel inlet protection device when storage capacity has been approximately 50 percent filled. Gravel will be cleaned or replaced when the sediment pool no longer drains properly.
4. Sediment will be removed from behind the sediment fence when it becomes about ½ foot deep at the fence. The sediment fence will be repaired as necessary to maintain a barrier.
5. All seeded areas will be fertilized, reseeded as necessary, and mulched according to specifications in the Vegetation Plan to maintain a vigorous, dense vegetative cover.

Note: The appropriate official from Anytown, Massachusetts should conduct regular (weekly or bi-weekly) inspections of the site and control measures to ensure proper functioning. Orders should be issued if any conservation practice is observed to be malfunctioning or incorrectly built.

References

Massachusetts Department of Environmental Protection, Office of Watershed Management, Nonpoint Source Program, ***Massachusetts Nonpoint Source Management***, Boston, Massachusetts, June, 1993.

Glossary

Access road: A temporary or permanent road over which timber is transported from a loading site to a public road. Also known as a haul road.

Acre-foot: An engineering term used to denote a volume 1 acre in area and 1 foot in depth.

Adsorption: The adhesion of one substance to the surface of another.

Aggrade: The alteration of a channel caused by the deposition of sediment.

Aggregate: The stone or rock gravel needed for an infiltration practice, such as an infiltration trench or dry well.

Alignment: The horizontal route or direction of an access road.

Alluvial: Pertaining to material that is transported and deposited by running water.

Allochthonous: Derived from outside a system, such as leaves of terrestrial plants that fall into a stream.

Angle of repose: The maximum slope or angle at which a material, such as soil or loose rock, remains stable. Angle between the horizontal and the maximum slope that a soil assumes through natural processes.

Anti-seep Collar: A device constructed around a pipe or other conduit placed through a dam, dike, or levee for the purpose of reducing seepage losses and piping failures.

Anti-vortex Device: A facility placed at the entrance to a pipe conduit structure such as a drop inlet spillway or hood inlet spillway to prevent air from entering the structure when the pipe is flowing full.

Apron: A floor or lining to protect a surface from erosion, for example, the pavement below chutes, spillways, or at the toes of dams. Erosion protection placed below the streambed in an area of high flow velocity, such as downstream from a culvert.

Aquifer: A geologic formation or structure that transmits water in sufficient quantity to supply the needs for a water development; usually saturated sands, gravel, fractures, and cavernous and vesicular rock (Soil Conservation Society of America, 1982).

Autochthonous: Derived from within a system, such as organic matter in a stream resulting from photosynthesis by aquatic plants.

Backfill: The operation of filling an excavation after it has once been made.

Backwater: The water retarded upstream of a dam or backed up into a tributary by a flood in the main stream.

Bankfull event (also bankfull discharge): A flow condition in which streamflow completely fills the steam channel up to the top of the bank. In undisturbed watersheds, the discharge condition occurs on average every 1.5 to 2 years and controls the shape and form of natural channels. (Schueler, 1987)

Barrel: The concrete or corrugated metal pipe of a principal spillway that passes runoff from the riser through the embankment, and finally discharges to the ponds outfall.

Base Flow: The stream discharge from groundwater runoff.

Bedding: (1) The process of laying a drain or other conduit in its trench and tamping earth around the conduit to form its bed. The manner of bedding may be specified to conform to the earth load and conduit strength. (2) A site preparation technique whereby a small ridge of surface soil is formed to provide an elevated planting or seed bed. It is used primarily in wet areas to improve drainage and aeration for seeding.

Bedload: The sediment that moves by sliding, rolling, or bounding on or very near the streambed; sediment moved mainly by tractive or gravitational forces or both but at velocities less than the surrounding flow.

Bedrock: The more or less solid rock in place either on or beneath the surface of the earth. It may be soft or hard and have a smooth or irregular surface.

Berm: (1) A horizontal strip or shelf built into an embankment or cut, to break the continuity of a long slope, usually for the purpose of reducing erosion, improving stability, or to increase the thickness or width of an embankment. (2) A low earth fill constructed in the path of flowing water to divert its direction, or constructed to act as a counterweight beside the road fill to reduce the risk of foundation failure (buttress).

Best Management Practice (BMP): A structural, nonstructural, or managerial technique recognized to be the most effective and practical means to prevent and reduce nonpoint source pollutants. Should be compatible with the productive use of the resource to which applied and should be cost effective.

Blind Drain: A type of drain consisting of an excavated trench refilled with previous materials, such as coarse sand, gravel or crushed stones, through whose voids water percolates and flows toward an outlet. Often referred to as a French drain because of its initial development and widespread use in France.

Bordering Vegetated Wetlands: Freshwater wetlands which border on creeks, rivers, streams, ponds, and lakes. The types of freshwater wetlands are wet meadows, marshes, swamps, and bogs. They are areas where the topography is low and flat, and where the soils are annually saturated.

Borrow Area: A source of earth fill materials used in the construction of embankments or other earth fill structures.

Borrow pit: An excavation site outside the limits of construction that provides necessary material, such as fill material for embankments.

Bottomlands: A term often used to define lowlands adjacent to streams (flood plains in rural areas).

Broad-based dip: A surface drainage structure specifically designed to drain water from an access road while vehicles maintain normal travel speeds.

Brush barrier: A sediment control structure created of slash materials piled at the toe slope of a road or at the outlets of culverts, turnouts, dips, and water bars.

Buffer area: A designated area around a stream or waterbody of sufficient width to minimize entrance of sediment and pollutants into the waterbody.

Cantilever Outlet: A discharge pipe extending beyond its support.

Catch Basin: An underground basin combined with a storm sewer inlet to trap solids.

Channel Erosion: The widening, deepening, and headward cutting of small channels and waterways, due to erosion caused by flowing water.

Channel: An open cut in the earth's surface, either natural or artificial, that conveys water.

Check dam: A small dam constructed in a gully to decrease the flow velocity, minimize channel scour, and promote deposition of sediment.

Chemigation: The addition of one or more chemicals to the irrigation water.

Chemigated water: Water to which fertilizers or pesticides have been added.

Chopping: A mechanical treatment whereby vegetation is concentrated near the ground and incorporated into the soil to facilitate burning or seedling establishment.

Chute: A device constructed to convey water on steep grades, lined with erosion resistant materials.

Composting: A controlled process of degrading organic matter by microorganisms.

Conduit: A closed facility used for the conveyance of water.

Constructed wetlands: Those wetlands that are intentionally created on sites that are not wetlands for the primary purpose of wastewater or urban runoff treatment and are managed as such.

Contour: An imaginary line on the surface of the earth connecting points of the same elevation. A line drawn on a map connecting points of the same elevation.

Conveyance system: The drainage facilities, both natural and human-made, which collect, contain, and provide for the flow of surface water and urban runoff from the highest points on the land down to a receiving water. The natural elements of the conveyance system include swales and small drainage courses, streams, rivers, lakes, and wetlands. The human-made elements of the conveyance system include gutters, ditches, pipes, channels, and most retention/detention facilities (Washington Department of Ecology, 1992).

Cover crop: A close-growing crop grown primarily for the purpose of protecting and improving soil between periods of regular crop production or between trees and vines in orchards and vineyards (Soil Conservation Society of America, 1982).

Cradle: A device, usually concrete, used to support a pipe conduit.

Crop residue: The portion of a plant or crop left in the field after harvest.

Crop rotation: The growing of different crops in recurring succession on the same land.

Crown: A convex road surface that allows runoff to drain to either side of the road prism.

Cubic foot per second: Rate of fluid flow at which 1 cubic foot of fluid passes a measuring point in 1 second. Abbreviated: cfs. Synonym: Second-foot; CUSEC.

Culvert: A metal, wooden, plastic, or concrete conduit through which surface water can flow under or across roads.

Culvert, Box: Generally a rectangular or square concrete structure for carrying large amounts of water under a roadway.

Cut-and-Fill: Process of earth moving by excavating part of an area and using the excavated material for adjacent embankments of fill areas.

Cutoff Trench: A long, narrow excavation constructed along the centerline of a dam, dike, levee, or embankment and filled with relatively impervious material intended to reduce seepage of water through porous strata.

Dam: A barrier to confine or raise water for storage or diversion, to create a hydraulic head, to prevent gully erosion, or for retention of soil, rock, or other debris.

Defoliant: A herbicide that removes leaves from trees and growing plants.

Denitrification: The anaerobic biological reduction of nitrate nitrogen to nitrogen gas.

Deposition: The accumulation of material dropped because of a slackening movement of the material-water or wind (Soil Conservation Society of America, 1982).

Desiccant: A chemical agent used to remove moisture from a material or object (Soil Conservation, of America, 1982).

Design Storm: A rainfall event of specific frequency and duration (e.g., a storm with a 2-year frequency and 24-hour duration) that is used to calculate runoff volume and peak discharge rate.

Detention: The temporary storage of storm runoff; used to control the peak discharge rates, and which provides settling of pollutants.

Detention Storage: The storage of storm runoff water for controlled release during or immediately following the design storm.

Detention Time: The amount of time that runoff water actually is stored. Theoretical detention time for a runoff event is the average time runoff of water resides in the basin over a period of release.

Dike: A temporary berm or ridge of compacted soil that channels water to a desired location. An embankment to confine or control water, especially one built along the banks of a river to prevent overflow of lowlands; a levee.

Disking (harrowing): A mechanical method of scarifying the soil to reduce competing vegetation and to prepare a site to be seeded or planted.

Diversion: A channel with a supporting ridge on the lower side constructed across or at the bottom of a slope for the purpose of intercepting surface runoff.

Drain: Usually a pipe, ditch, or channel for collecting and conveying water.

Drainage: A general term applied to the removal of surface or subsurface water from a given area either by gravity or by pumping.

Drainage area: The contributing area to a single drainage basin, expressed in acres, square miles, or other unit of area.

Drainage structure: Any device or land form constructed to intercept and/or aid surface water drainage.

Dry Well: An excavated pit backfilled with aggregate or a constructed chamber placed in an excavation and backfilled with aggregate around the chamber. Provides temporary runoff storage and allows stored runoff to infiltrate into the soil.

Duff: The accumulation of needles, leaves, and decaying matter on the forest floor.

Effluent: Solid, liquid, or gaseous wastes that enter the environment as a by-product of man-oriented processes (Soil Conservation Society of America, 1982).

Emergency or Earth Spillway: A depression in the embankment of a pond or basin that is used to pass peak discharges greater than the maximum design storm controlled by the pipe spillway of the pond.

Empirical: Originating in or relying or based on factual information, observation, or direct sense experience.

Ephemeral stream: A channel that carries water only during and immediately following rainstorms.

Equivalent Opening Size (EOS): Pertains to geotextile fabric filter. It is the Equivalent Opening Size of the fabric as it relates to the US Standard Sieve Designation used in Soil Mechanics Laboratories.

Erosion: Wearing away of land by running water, waves, wind, ice, abrasion, and transportation.

Fallow: Allowing cropland to lie idle, either tilled or untilled, during the whole or greater portion of the growing season (Soil Conservation Society of America, 1982).

Field capacity: The soil-water content after the force of gravity has drained or removed all the water it can, usually 1 to 3 days after rainfall.

Fill slope: The surface formed where earth is deposited to build a road or trail.

Filter Fabric: Textile of relatively small mesh or pore size that is used to (1) allow water to pass through while keeping sediment out (permeable), or (2) prevent both runoff and sediment from passing through (impermeable).

Filter fence: A temporary barrier used to intercept sediment-laden runoff from small areas.

Flood: Water from a river, stream, watercourse, ocean, lake, or other body of standing water that temporarily overflows or inundates adjacent lands and which may affect other lands and activities through stage elevation, backwater and/or increased ground water level.

Flood Control: The elimination or reduction of flood losses by the construction of flood storage reservoirs, channel improvements, dikes and levees, by-pass channels, or other engineering works.

Flood Frequency: See “Recurrence Interval.”

Flood Plain: For a given flood event, that area of land adjoining a continuous watercourse which has been covered temporarily by flood water.

Flood Storage: Storage of water during floods to reduce downstream peak flows.

Flood Storage Area: Flood storage area is that portion of the impoundment area that may serve as a temporary storage area for flood waters.

Flume: An open conduit on a prepared grade, trestle, or bridge for the purpose of carrying water across creeks, gullies, ravines, or other obstructions; also used in reference to calibrated devices used to measure the flow of water in open conduits (Soil Conservation Society of America, 1982).

Forb: A broad-leaf herbaceous plant that is not a grass, sedge, or rush.

Ford: Submerged stream crossing where tread is reinforced to bear intended traffic.

Freeboard: The vertical distance from the top of an embankment to the highest water elevation expected for the largest design storm stored. The space is required as a safety margin in a pond or basin.

Geotextile: A product used as a soil reinforcement agent and as a filter medium. It is made of synthetic fibers manufactured in a woven or loose nonwoven manner to form a blanket-like product.

Grade: (1) The inclination or slope of a channel, conduit, etc., or natural ground surface, usually expressed in terms of the percentage of number of units of vertical rise (or fall) per unit of horizontal distance. (2) To finish the soil surface, a roadbed, top of embankment, bottom of excavation, etc.

Grade Stabilization Structure: A permanent structure used to drop water from a higher elevation to a lower elevation without causing erosion.

Grassed Waterway or Outlet: A natural or constructed channel shaped or graded and established with suitable vegetation as needed for the safe disposal of runoff water.

Headwater: (1) The upper reaches of a stream near its source; (2) the region where ground waters emerge to form a surface stream; or (3) the water upstream from a structure.

Heavy metals: Metallic elements with high atomic weights, e.g., mercury, chromium, cadmium, arsenic, and lead. They can damage living things at low concentrations and tend to accumulate in the food chain.

Herbaceous: A vascular plant that does not develop woody tissue (Soil Conservation Society of America, 1982).

Herbicide: A chemical substance designed to kill or inhibit the growth of plants, especially weeds (Soil Conservation Society of America, 1982).

High water mark: See Ordinary high water mark.

Highly erodible soils: Any soil with an erodibility class (K factor) greater than or equal to .43 in any layer.

Holding pond: A reservoir, pit, or pond, usually made of earth, used to retain polluted runoff water for disposal on land (Soil Conservation Society of America, 1982).

Hybrid: A plant resulting from a cross between parents of different species, subspecies, or cultivar (Soil Conservation Society of America, 1982).

Hydraulic gradient: A profile of the piezometric level of the water, representing the sum of the depth of flow and the pressure. In open channel flow it is the water surface.

Hydric soil: A soil that is saturated, flooded, or ponded long enough during the growing season to develop anaerobic conditions in the upper part.

Hydrograph: A graph showing variation in the water depth or discharge in a strewn or channel versus time.

Hydrology: The science that deals with the processes governing the depletion and replenishment of the water resources of the land areas of the earth.

Hydrophyte: A plant that grows in water or in wet or saturated soils (Soil Conservation Society of America, 1982).

Impervious: A term applied to a material through which water cannot pass, or through which water passes with great difficulty.

Impervious Area: Impermeable surfaces, such as pavement or rooftops, which prevent the infiltration of water into the soil.

Inert: A substance that does not react with other substances under ordinary conditions.

Infiltration: The penetration of water through the ground surface into subsurface soil.

Infiltration Trench: An excavated trench, usually 2 to 10 feet deep that is backfilled with a coarse graded stone aggregate. It provides temporary storage of runoff and permits infiltration into the surrounding soil.

Insecticide: A pesticide compound specifically used to kill or control the growth of insects.

Interflow: The portion of rainfall that infiltrates into the soil and moves laterally through the upper soil horizons until intercepted by a stream channel or until it returns to the surface in, for example, a wetland, spring, or seep.

Intermittent stream: A watercourse that flows in a well-defined channel only in direct response to a precipitation event. It is dry for a large part of the year.

Invert: The floor, bottom, or lowest portion of the internal cross section of a conduit.

Lateral: Secondary or side channel, ditch, or conduit (Soil Conservation Society of America, 1982).

Leachate: Liquids that have percolated through a soil and that contain substances in solution or suspension (Soil Conservation Society of America, 1982).

Leaching: The removal from the soil in solution of the more soluble materials by percolating waters (Soil Conservation Society of America, 1982).

Legume: A member of a large family that includes many valuable food and forage species, such as peas, beans, peanuts, clovers, alfalfas, sweet clovers, lespedezas, vetches, and kudzu (Soil Conservation Society of America, 1982).

Levee: See Dike.

Level Spreader: An outlet constructed at zero percent grade across the slope that allows concentrated runoff to be discharged as sheet flow at a non-erosive velocity onto natural or man-made areas that have existing vegetation capable of preventing erosion.

Micronutrient: A chemical element necessary in only extremely small amounts (less than 1 part per million) for the growth of plants (Soil Conservation Society of America, 1982).

Mineral soil: Organic-free soil that contains rock less than 2 inches in maximum dimension.
Mulch: A natural or artificial layer of plant residue or other materials covering the land surface that conserves moisture, holds soil in place, aids in establishing plant cover, and minimizes temperature fluctuations.

Mulching: Providing any loose covering, such as grass, straw, bark, or wood fibers, for exposed soils to help control erosion and protect exposed soil.

Nonpoint source: Any source of water pollution that does not meet the legal definition of "point source" in section 502(14) of the Clean Water Act. Nonpoint source pollution generally results from land runoff, precipitation, atmospheric deposition, drainage, seepage, or hydrologic modification.

Nutrients: Elements, or compounds, essential as raw materials for organism growth and development, such as carbon, nitrogen, phosphorus, etc. (Soil Conservation Society of America, 1982).

Ordinary high water mark: An elevation that marks the boundary of a lake, marsh, or streambed. It is the highest level at which the water has remained long enough to leave its mark on the landscape. Typically, it is the point where the natural vegetation changes from predominantly aquatic to predominantly terrestrial. The line on the shore established by the fluctuations of water and indicated by physical characteristics such as a clear, natural line impressed on the bank; shelving; changes in the character of soil destruction on terrestrial vegetation, or the presence of litter and debris; or other appropriate means that consider the characteristics of the surrounding area.

Organic debris: Particles of vegetation or other biological material that can degrade water quality by decreasing dissolved oxygen and by releasing organic solutes during leaching.

Organophosphate: Pesticide chemical that contains phosphorus, used to control insects. Organophosphates are shortlived, but some can be toxic when first applied.

Outlet Protection: A rock lined apron or other acceptable energy dissipating material placed at the outlet of a pipe or paved channel and a stable downstream receiving channel.

Outslope: To shape the road surface to cause drainage to flow toward the outside shoulder.

Paved flume: A permanent lined channel constructed on a relatively steep slope. Its purpose is to conduct concentrated runoff down the slope without causing an erosion problem either on the slope or at the outlet.

Peak discharge: The maximum instantaneous rate of now during a storm, usually in reference to a specific design storm event.

Peak rate of runoff: The maximum rate of runoff during a given runoff event.

Pervious: A term applied to a material through which water passes relatively freely.

Percolation: The downward movement of water through the soil (Soil Conservation Society of America, 1982).

Perennial plant: A plant that has a life span of 3 or more years (Soil Conservation Society of America, 1982).

Perennial stream: A watercourse that flows throughout a majority of the year in a well-defined channel.

Permanent storage: The portion of a pond or infiltration BMP which is below the elevation of the lowest outlet of the structure.

Permanent wilting point: The soil water content at which healthy plants can no longer extract water from the soil at a rate fast enough to recover from wilting. The permanent wilting point is considered the lower limit of plant-available water.

Permeability: The quality of a soil horizon that enables water or air to move through it; may be limited by the presence of one nearly impermeable horizon even though the others are permeable (Soil Conservation Society of America, 1982).

Pesticide: Any chemical agent used for control of plant or animal pests. Pesticides include insecticides, herbicides, fungicides, nematocides, and rodenticides.

Pioneer roads: Temporary access ways used to facilitate construction equipment access when building permanent roads.

Plant-available water: The amount of water held in the soil that is available to plants; the difference between field capacity and the permanent wilting point.

Point source: Any discernible, confined and discrete conveyance, including but not limited to any pipe, ditch, channel, tunnel, conduit, well, discrete fissure, container, rolling stock, concentrated animal feeding operation, or vessel or other floating craft, from which pollutants are or may be discharged.

Pollutant: Dredged spoil, solid waste, incinerator residue, sewage, garbage, sewage sludge, munitions, chemical wastes, biological materials, radioactive materials, heat, wrecked or discarded equipment, rock, sand, cellar dirt, and industrial, municipal, and agricultural waste discharged into water (Section 502(6) of The Clean Water Act as amended by the Water Quality Act of 1987, Pub. L. 100-4).

Postdevelopment peak runoff: Maximum instantaneous rate of flow during a storm, after development is complete.

Precipitation: Any moisture that falls from the atmosphere, including snow, sleet, rain, and hail.

Principal or Pipe Spillway: A pipe structure normally consisting of a vertical conduit (riser) and a horizontal outlet conduit (barrel). It is used to control the water level and the discharge from a pond or basin.

Rainfall data: The average depth, in inches, of rainfall occurring over a watershed or subwatershed for a given frequency and duration storm event.

Reach: Any length of river or channel. Usually used to refer to sections which are uniform with respect to discharge, depth, area or slope, or sections between gaging stations.

Recurrence interval: The average interval of time within which a given event will be equalled or exceeded once. For an annual series the probability in any one year is the inverse of the recurrence interval. Thus a flood having a recurrence interval of 100 years (100-year frequency storm) has a 1 percent probability of being equalled or exceeded in any one year.

Release rate: The rate of discharge in volume per unit time from a detention facility.

Residue: See crop residue.

Retarding basin: A basin storage designed and operated to reduce the flood flows of a stream through temporary storage.

Retention: The holding of runoff in a basin without release except by means of evaporation, infiltration, or emergency bypass.

Retention storage: The storage of storm runoff water for release after the end of the design storm at a time and in amounts that can be conveniently handled by, the drainage system.

Return flow: That portion of the water diverted from a stream that finds its way back to the stream channel either as surface or underground flow (Soil Conservation Society of America, 1982).

Right-of-way: The cleared area along the road alignment that contains the roadbed, ditches, road slopes, and back slopes.

Riprap: A combination of graded stone, cobbles, and boulders used to protect streambanks, bridge abutments, or other erodible sites from runoff or wave action.

Riser: A vertical pipe connected to a barrel, extending from the bottom of a pond that is used to control the discharge rate for a specific design storm.

Root zone: The part of the soil that is, or can be, penetrated by plant roots (Soil Conservation Society of America, 1982).

Runoff: That part of precipitation or snow melt that runs off the land into streams or other surface water.

Runoff Curve Number: A factor in the NRCS/SCS Hydrologic Soil Cover Complex runoff determination method. Relates mass rainfall to mass runoff. It is based on soil characteristics, cover type and land treatment.

Salinity: The concentration of dissolved solids or salt in water (Soil Conservation Society of America, 1982).

Scour: Soil erosion when it occurs underwater, as in the case of a streambed.

Seed bed: The soil prepared by natural or artificial means to promote the germination of seeds and the growth of seedlings.

Sediment: The product of erosion processes, the solid material, both mineral and organic, that is in suspension, is being transported, or has been moved from its site of origin by air, water, gravity, or ice.

Sediment Basin: A basin constructed to collect and store sediment or other waterborne debris.

Sedimentation: The process or act of depositing sediment (Soil Conservation Society of America, 1982).

Seepage: Water escaping through or emerging from the ground along an extensive line or surface as contrasted with a spring, where the water emerges from a localized spot (Soil Conservation Society of America, 1982).

Settleable solids: Solids in a liquid that can be removed by stilling a liquid. Settling times of one hour or more are generally used.

Sheetflow: Water, usually storm runoff, flowing in a thin layer over the ground surface.

Silt fence: A temporary barrier used to intercept sediment-laden runoff from small areas.

Sinkhole: A depression in the earth's surface caused by dissolving of underlying limestone, salt, or gypsum; drainage is through underground channels; may be enlarged by collapse of a cavern roof (Soil Conservation Society of America, 1982).

Slope: Amount of deviation of a surface from the horizontal, measured as a numerical ratio, as a percent, or in degrees. Expressed as a ratio, the first number is the horizontal distance (run) and the second number is the vertical distance (rise), as 2:1. A 2:1 slope is a 50 per cent slope. Expressed in degrees, the slope is the angle from the horizontal plane, with a 90 degree slope being vertical (maximum) and a 45 degree slope being a 1:1 slope.

Sludge: The material resulting from chemical treatment of water, coagulation, or sedimentation (Soil Conservation Society of America, 1982).

Soil profile: A vertical section of the soil from the surface through all its horizons, including C horizons (Soil Conservation Society of America, 1982).

Soil survey: A general term for the systematic examination of soils in the field and in laboratories; their description and classification; the mapping of kinds of soil; the interpretation of soils according to their adaptability for various crops, grasses, and trees; their behavior under use or treatment for plant production or for other purposes; and their productivity under different management systems (Soil Conservation, Society of America, 1982).

Storm Sewer: A closed conduit for conducting storm water that has been collected by inlets or by other means.

Storm Runoff: The water from precipitation running off from the surface of a drainage area during and immediately following a period of rain.

Straw or Hay Bale Barrier: A temporary obstruction of straw or hay installed across or at the toe of a slope. It intercepts and detains small amounts of sediment from unprotected areas of limited extent and reduce runoff velocity down the slope.

Subsurface Drain: A conduit such as tile, pipe or plastic tubing, installed beneath the ground surface that collects and/or conveys excess water emanating from the soil.

Surface detention: The storm runoff detained on the surface of the ground at or near where the rainfall occurred, and which will either run off slowly or infiltrate into the soil.

Surface infiltration: That rainfall which percolates into the ground surface and which therefore does not contribute directly to the storm runoff flow.

Surface water: All water whose surface is exposed to the atmosphere.

Suspended sediment: The very fine soil particles that remain in suspension in water for a considerable period of time.

Swale: A natural depression or wide shallow ditch used to temporarily store, route, or filter runoff.

Temporary sediment trap: A small temporary ponding area that is formed by excavation or constructing an earthen embankment across a drainageway to reduce flow velocities thus allowing soil particles to fall out of suspension before discharging into the downstream waters.

Temporary Grade Stabilization Structure: A temporary barrier of rock, timber or straw or hay bales constructed across a swale or drainage ditch to reduce flow velocity.

Tillage: The operation of implements through the soil to prepare seedbeds and rootbeds, control weeds and brush, aerate the soil, and cause faster breakdown of organic matter and minerals to release plant foods (Soil Conservation Society of America, 1982).

Tilth: The physical condition of the soil as related to its ease of tillage, its fitness as a seedbed, and its impedance to seedling emergence and root penetration (Soil Conservation Society of America, 1982).

Time of Concentration: The time required for surface runoff from the most hydraulically remote part of a drainage basin to reach the basin outlet or the point under consideration.

Time of Flow: The time required for water to flow in a storm drain from the point where it enters to any given point or location beyond the inlet.

Topography: The relative positions and elevations of the natural or man-made features of an area that describe the configuration of its surface (Soil Conservation Society of America, 1982).

Trash rack: A barrier constructed to catch debris and exclude it from entering a downstream conduit.

Trench: An excavation made for installing pipes, masonry walls, and other purposes. A trench is distinguished from a ditch in that the opening is temporary and is eventually backfilled.

Turbidity: A cloudy condition in water due to suspended silt or organic matter.

Turnout: A drainage ditch that drains water away from roads and road ditches.

Vegetated buffer: Strips of vegetation separating a waterbody from a land use with potential to act as a nonpoint pollution source; vegetated buffers (or simply buffers) are variable in width and can range in function from a vegetated filter strip to a wetland or riparian area.

Vegetated filter strip: An area of vegetation for runoff to flow through when it leaves a disturbed site before it enters into a designed drainage system.

Vegetated swale: A natural or constructed broad channel with dense vegetation designed to treat runoff and dispose of it safely into the natural drainage system. Swales are designed to remove pollutants from stormwater runoff, increase infiltration and reduce the erosion potential at the discharge point.

Water bar: A diversion ditch and/or hump installed across a trail or road to divert runoff from the surface before the flow gains enough volume and velocity to cause soil movement and erosion, and deposit the runoff into a dispersion area.

Watercourse: A definite channel with bed and banks within which concentrated water flows continuously, frequently or infrequently.

Water table: The upper surface of the ground water or that level below which the soil is saturated with water; locus of points in soil water at which the hydraulic pressure is equal to atmospheric pressure (Soil Conservation Society of America, 1982).

Watershed: A drainage area or basin in which all land and water areas drain or flow toward a central collector such as a stream, river, or lake at a lower elevation.

Weir: Device for measuring or regulating the flow of water.

Wetlands: Areas that are inundated or saturated by surface or ground water at a frequency and duration to support, and that under normal circumstances do support, a prevalence of vegetation typically adapted for life in saturated soil conditions; wetlands generally include swamps, marshes, bogs, and similar areas.

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